

## **Engineering Design File**

# **Fate and Transport Modeling Results and Summary Report**



Form 412.14  
10/9/2003  
Rev. 05

431.02  
01/30/2003  
Rev. 11

# ENGINEERING DESIGN FILE

EDF-ER-275  
Revision 3  
Page 1 of 229

EDF No.: EDF-ER-275 EDF Rev. No.: 3 Project File No.: NA

1. Title: Fate and Transport Modeling Results and Summary Report

2. Index Codes: NA

Building/Type NA SSC ID NA Site Area NA

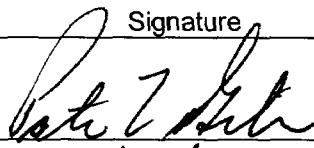
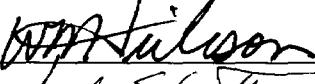
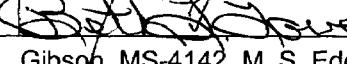
3. NPH Performance Category: \_\_\_\_\_ or  N/A

4. EDF Safety Category: \_\_\_\_\_ or  N/A SCC Safety Category: \_\_\_\_\_ or  N/A

5. Summary:

Fate and transport modeling was conducted to evaluate potential long-term concentrations in the Snake River Plain Aquifer that could result from transport of landfill constituents from the Idaho National Engineering and Environmental Laboratory Comprehensive Environmental Response, Compensation, and Liability Act Disposal Facility. Fate and transport simulations were conducted to identify contaminants of concern (COCs) with respect to meeting groundwater remedial action objectives (RAOs). Numerical modeling was performed using the Subsurface Transport Over Multiple Phases (STOMP) computer code to identify dilution/attenuation factors for a selected suite of contaminants. These factors were subsequently applied to the remaining contaminants in the facility design basis inventory to identify those contaminants that may pose a potential risk and to prepare RAO-based waste soil concentration limits. This report provides results and findings from fate and transport simulations.

6. Review (R) and Approval (A) and Acceptance (Ac) Signatures:  
(See instructions for definitions of terms and significance of signatures.)

	R/A	Typed Name/Organization	Signature	Date
Independent Peer Reviewer (if applicable)		Pat Gibson		8/15/04
Document Owner		W. Mahlon Heileson		8/10/04
Requestor		Mike Edgett		8/10/04
Doc. Control		BETH LOVE		8-12-04

7. Distribution:  
(Name and Mail Stop) W. M. Heileson, MS-4142, P. L. Gibson, MS-4142, M. S. Edgett, MS-4142

8. Does document contain sensitive unclassified information?  Yes  No  
If Yes, what category:

9. Can document be externally distributed?  Yes  No

10. Uniform File Code: 6102 Disposition Authority: ENV1-h-1

Record Retention Period: 25 years after project See LIST 9

11. For QA Records Classification Only:  Lifetime  Nonpermanent  Permanent  
Item and activity to which the QA Record apply:

12. NRC related?  Yes  No

EDF No.: EDF-ER-275 EDF Rev. No.: 3 Project File No.: NA

1. Title: Fate and Transport Modeling Results and Summary Report

2. Index Codes: NA

Building/Type NA SSC ID NA Site Area NA

13. Registered Professional Engineer's Stamp (if required)

## **ABSTRACT**

This report describes the fate and transport modeling conducted to support the determination of remedial action objective-based waste soil concentrations for design basis contaminants intended for disposal at the INEEL CERCLA Disposal Facility. The modeling results provide contaminant travel time and concentration at the point of assessment for the 1,000-year facility design life and a 1,000,000-year evaluation period. The modeled concentrations are compared against the groundwater remedial action objective criteria. The results are intended to provide the methodology and starting point for adjusting design inventory concentrations resulting in the preliminary waste acceptance criteria for the complex. The results also support the evaluation of the design performance requirements of the INEEL CERCLA Disposal Facility final cover barrier.

431.02  
01/30/2003  
Rev. 11

**ENGINEERING DESIGN FILE**

EDF-ER-275  
Revision 3  
Page 4 of 228

This page intentionally left blank.

## **CONTENTS**

ABSTRACT .....	3
ACRONYMS .....	7
1. INTRODUCTION .....	9
2. FATE AND TRANSPORT MODELING METHODS.....	11
2.1 Modeling Approach.....	11
2.1.1 Modeling Analytical Equations and Numerical Calculations .....	12
2.1.2 Model Calibration and Validation.....	13
2.1.3 Model Construction.....	15
2.1.4 Model Output .....	21
2.2 Model Results.....	21
2.2.1 Radioactive Progeny .....	25
2.2.2 Sensitivity Analysis.....	26
2.2.3 Estimated Efficacy of Design Cover Recharge Reduction .....	27
3. CONCLUSIONS .....	28
4. REFERENCES .....	28
Appendix A—Verification of STOMP Model Numerical Results for the Design of the ICDF .....	31
Appendix B—Evaluation of Design Concentrations as Compared to the Remedial Action Objectives .....	43
Appendix C—Calculation of Groundwater Risk Based Concentrations .....	87
Appendix D—Effects of Recharge Rate Change on Remedial Action Objectives.....	115
Appendix E—STOMP Input Files.....	121
Appendix F—Analysis of Fate and Transport for the ICDF Landfill Waste Acceptance Criteria .....	213

## **FIGURES**

1. Comparison of the van Genuchten moisture content (saturation)-capillary pressure relationship to the TETRAD Brooks-Corey equation.....	15
2. Conceptual model of ICDF vertical profile .....	18
3. Numerical model grid and boundary conditions of ICDF vertical profile .....	19
4. Residual moisture and capillary pressure initial conditions for transport simulations using STOMP.....	20

5. Example contaminant arrival curves at the assessment point for Surrogate 4 and three uranium isotopes at the design recharge/infiltration rate ..... 22

## **TABLES**

1. Contaminant distribution coefficients and weighted averages for the different surrogates and model layer types .....	10
2. Comparison of STOMP and screening model results (EDF-ER-170 [Martian 2000]) with attenuation barrier at ICDF bounding inventory values.....	14
3. Summary of soil properties and moisture content (saturation)-aqueous pressure relationship curve fit parameters.....	16
4. Summary of soil hydraulic and contaminant transport properties .....	17
5. Results of surrogate contaminant transport simulations and example radionuclide dilution/attenuation factors and peak arrival times at maximum design recharge rate .....	23
6. Results of selected contaminant transport simulations at maximum design recharge rate (0.0001 m/yr) scaled to ICDF inventory .....	24
7. Results of selected radioactive daughter product transport simulations at maximum design recharge rate scaled to ICDF inventory of all parents .....	26
8. Results of selected radioactive daughter product transport simulations at maximum design recharge rate scaled to ICDF inventory of all parents .....	26
9. Comparison of estimated carcinogenic risk, cumulative HI, and alpha-emitter concentration in groundwater during the 1,000-year design life at the ICDF at background recharge rate and design cover recharge rate .....	28

## **ACRONYMS**

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	contaminant of concern
DAF	dilution/attenuation factor
EDF	engineering design file
ELCR	excess lifetime carcinogenic risk
EPA	Environmental Protection Agency
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
ICDF	INEEL CERCLA Disposal Facility
INEEL	Idaho National Engineering and Environmental Laboratory
IRIS	Integrated Risk Information System
MCL	maximum contaminant level
NCEA	National Center for Environmental Assessment
PNNL	Pacific Northwest National Laboratories
RAO	remedial action objectives
RBC	risk-based concentrations
RBL	risk-based level
RI	Remedial Investigation
ROD	Record of Decision
SRPA	Snake River Plain Aquifer
STOMP	Subsurface Transport Over Multiple Phases (transport modeling code)
WAG	waste area group

431.02  
01/30/2003  
Rev. 11

**ENGINEERING DESIGN FILE**

EDF-ER-275  
Revision 3  
Page 8 of 228

This page intentionally left blank.

# Fate and Transport Modeling Results and Summary Report

## 1. INTRODUCTION

The purpose of the contaminant transport simulations was to develop attenuation factors and travel time estimates for the contaminants of concern (COC) consistent with the facility design basis inventory presented in "INEEL CERCLA Disposal Facility Design Inventory" (EDF-ER-264).

Performance of fate and transport modeling is primarily driven by the requirements of the Record of Decision (ROD). The scope of the modeling effort was limited to the constituents presented in the design inventory. However, the simulations were performed in a manner that allows constituents not included in the design inventory to be easily included. The objectives of the modeling effort were as follows:

- To develop dilution/attenuation factors for use in evaluating travel times and resultant contaminant concentrations in groundwater at an assessment point downgradient of the Idaho National Engineering and Environmental Laboratory (INEEL) Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Disposal Facility (ICDF) facility.
- To develop a set of waste soil concentration limits based on meeting the groundwater remedial action objectives (RAOs) of not exceeding maximum contaminant levels (MCLs) or risk-based concentrations (RBCs) in groundwater downgradient of the ICDF.
- To evaluate the effectiveness of the planned final cover for the ICDF by utilizing the anticipated cover infiltration rate as one of the inputs for the contaminant fate and transport model.
- To support development of waste acceptance criteria by providing the RAO-based soil concentrations.

Several hydrologic investigations and modeling studies have been conducted previously. The current modeling effort incorporates the previous information as well as results of site-specific data collection activities and facility-specific design parameters to provide an estimate of the transport scenarios in the vadose zone. Insufficient data exist to calibrate the model, especially considering the complexity of the vadose zone geology and other hydrologic features (e.g., the Big Lost River). The time duration of the model (1,000,000 years) is so great that the results for distant outyears contain a large degree of uncertainty. The information, however, appears adequate for the purposes of setting waste soil concentration limits and preliminary acceptance criteria, and evaluating the necessary effectiveness of the planned final cover.

Dilution attenuation factors (DAF) represent the ratio between the initial concentration of the contaminant in the waste and the resulting concentration in the aquifer at the assessment point. Travel time refers to the time elapsed from the placement of the waste in the ICDF to the arrival of the peak concentration of the contaminant at the assessment point. Travel time depends on the hydrologic properties of the porous media (e.g., infiltration rate, soil bulk density, porosity, and moisture content), the radiologic and environmental decay characteristics of the contaminants, and the adsorption characteristics of the contaminants as described by their distribution coefficient. There are more than 300 COCs, so fate and transport of eight surrogate contaminants representing the expected range of contaminant distribution coefficients (and thus contaminant travel times) were simulated. The surrogates

selected for the modeling and their respective distribution coefficients are shown in Table 1. Although the modeling effort contained in this document focuses on the design inventory constituents, additional constituents that have not previously been included in the design inventory can easily be included by utilizing this approach, if they are identified during remedial activities. Attenuation factors and travel time estimates for contaminants not specifically modeled may be estimated from the results of the surrogate with similar transport characteristics ( $K_d$ ).

Table 1. Contaminant distribution coefficients and weighted averages for the different surrogates and model layer types.

Model Layer Type	Distribution Coefficient ( $K_d$ ) ( $\text{cm}^3/\text{g}$ )							
	Surrogate							
	1	2	3	4	5	6	7	8
Aquifer Layer								
SRPA basalt	0	0	0.008	0.24	0.32	0.48	0.64	13.6
Vadose Zone Layer								
Basalt	0	0	0	0	0	0	0	0
Interbed	0	0	0.2	6	8	12	16	340
Alluvium	0	0	0.2	6	8	24	16	340
Clay	0	1	1	63	55	200	2,400	340
Operations layer	0	0	0.2	6	8	12	16	340
Waste	0	0	0.2	6	8	12	16	340
Weighted average <sup>a</sup>	0.00	0.006	0.058	1.95	2.426	4.464	18.592	91.12

a. The weighted average vadose zone  $K_d$  is used only as an indicator of the relative mobility of specific contaminants in the vadose zone beneath the ICDF. The purpose of the weighted average  $K_d$  is to group constituents with similar distribution coefficients in the vadose zone with the appropriate surrogate. The weighted average  $K_d$  was computed by multiplying the fractional vadose zone thickness of each stratigraphic unit by the contaminant-specific  $K_d$  for each unit and summing the results.

The point of assessment was located in the upper portion (approximately 5 m) of the Snake River Plain Aquifer (SRPA) 20 meters (m) downgradient from the edge of the ICDF landfill surface barrier. The aquifer is approximately 76-m thick near the ICDF (Waste Area Group 3 Remedial Investigation Report). Previous modeling (Martian 2000) assumed an aquifer thickness equal to the assessment limit of 5 meters, but the Waste Area Group (WAG) 3 Remedial Investigation (RI) report indicates that assumption is unreasonably conservative based on the known thickness of the aquifer. For this simulation effort, the total aquifer thickness was specified as 76 m, although the groundwater contamination assessment interval was retained at 5 m thickness. This provides for a realistic aquifer thickness based on site-specific observation. Two recharge/infiltration rates were simulated to provide the range of expected results on the basis of barrier performance and background infiltration.

Existing hydrogeologic data and design specifications were used to provide input parameters for the fate and transport model. Sources of the data include previous modeling efforts (Martian 2000; Schafer et al. 1997), the Waste Area Group 3 Geotechnical Report (DOE-ID 2000), and input from the facility design requirements. Transport characteristics (distribution coefficients [ $K_d$ ]) for the COCs were previously inventoried for the vicinity of the ICDF (Jenkins 2001<sup>a</sup>). The distribution coefficients are

a. Jenkins, T., DOE, letter to Martin Doornbos, BBWI, July 3, 2001,  $K_d$  values for INTEC groundwater modeling (EM-ER-01-115).

included in the contaminant-specific information presented in Appendices A and B for radiological and non-radiological contaminants, respectively.

Several assumptions were made during the modeling, and are listed below. The assumptions fall into two basic groups: assumptions related to the conceptual model and inputs to the model.

Assumptions related to the conceptual model include the following:

- It is assumed that there is no lateral flow or transport beyond the lateral boundaries of the model domain. This assumption forces all flow in the model downward until it reaches groundwater.
- There is no influence from the wastewater disposal ponds or the Big Lost River.
- Incorporation of the Big Lost River influence would decrease the peak concentration at the assessment point. The influence of the Big Lost River on contaminant transport to the SRPA was previously analyzed in site modeling performed for development of the conceptual design report (Martian 2000). It was determined to have the effect of decreasing contaminant time of travel to the aquifer but also decreasing the concentrations due to dilution.
- Seasonal fluctuations in recharge are annualized over the 1,000,000-year evaluation period.
- The cover functionally moderates the seasonal fluctuations in recharge.
- Absence of catastrophic geologic/hydrologic events that would disrupt the landfill and/or final cover.
- Assumptions to input parameters to the model include the following:
  - Continued integrity of the final cover to maintain recharge at the design infiltration rate of 1E-04 m/yr (0.1 mm/yr) (EDF-ER-279).
  - A cap efficiency of 99% was assumed.
  - Precipitation not to exceed 300% of the historical precipitation as described in the hydrologic model of the final cover (EDF-ER-279).
  - No limitations to initial solubility of constituents in the landfill.

## **2. FATE AND TRANSPORT MODELING METHODS**

### **2.1 Modeling Approach**

The following section describes the methods used to simulate the fate and transport of COCs identified for disposal at the ICDF. The two-dimensional (vertical and horizontal parallel to groundwater flow) numerical model used to simulate the contaminant transport from the ICDF was developed according to the conceptual model presented in the report describing the screening model results (Martian 2000) and additional information regarding the construction of the ICDF itself.

The modeling effort used the Subsurface Transport Over Multiple Phases (STOMP) Version 2.0 finite difference code developed by Pacific Northwest National Laboratory (PNNL) to conduct the

simulations. A description of the STOMP code is found in the Theory Guide (PNNL 1996) and the User's Guide (PNNL 2000). STOMP capabilities include, among others, the simulation of saturated and unsaturated flow regimes, transport of decaying and non-decaying contaminants, and transport of aqueous phase organic compounds. A complete description of STOMP capabilities and the actual equations and the partial differential approximations are contained within the Theory Guide and User's Guide, and the Applications Guide (Nichols et al. 2000) provides information regarding code validation. An evaluation of vadose zone model codes recently conducted at the Hanford Site (Mann et al. 1999) ultimately resulted in the selection of STOMP for simulating high-level radioactive tank waste fate and transport (Mann 2001<sup>b</sup>). STOMP also includes aquifer fate and transport so that the vadose and aquifer portions of the modeling may be conducted within one model domain and simulation.

### **2.1.1 Modeling Analytical Equations and Numerical Calculations**

Quantitative predictions of hydrogeologic flow and contaminant transport are generated from the numerical solution of non-linear partial differential equations that describe subsurface environment flow and transport phenomena. Simulating water and contaminant transport through the vadose zone requires the solution of the non-linear partial differential equations used to describe flow through unsaturated porous media. Solution of the equations requires moisture retention (aqueous phase pressure and moisture content) and fluid transport (hydraulic conductivity and moisture content or aqueous phase pressure) characteristic data for the porous media contained within the model domain. The model uses functional relationships (referred to as characteristic curves) to describe the characteristic data. The equation (1) used in the model (as presented in PNNL 1996) and shown below was developed by van Genuchten (van Genuchten et al. 1991) to describe the moisture retention characteristic of the porous media:

$$S_w = \left\{ 1 + \left( \alpha \left[ \frac{P_g - P_w}{\rho_w g} \right] \right)^n \right\}^{-m} \quad \text{for } P_g - P_w > 0 \quad (1)$$
$$S_w = 1 \quad \text{for } P_g - P_w \leq 0$$

where

$S_w$  = degree of water saturation of the porous media (dimensionless)

$P_g$  = absolute pressure of the gas phase present (Pa, atmospheric pressure for these simulations)

$P_w$  = absolute pressure of the water phase present (Pa)

$\rho_w$  = density of water ( $\text{kg/m}^3$ )

$g$  = acceleration of gravity ( $\text{m/s}^2$ )

$\alpha$ (1/m), n, and m are curve fit parameters, and  $m = 1 - 1/n$  except for basalt.

The Mualem equation (as presented in PNNL 1996 and shown below) was used to describe hydraulic conductivity as a function of moisture content:

---

b. Frederick Mann, CH2M HILL, to McMahon, William J., CH2M HILL, November 5, 2001, "Information regarding Request for Proposal," (STOMP Requirements).

$$k_{rw} = (S_w)^{1/2} \{1 - (1 - [S_w]^{1/m})^m\}^2 \quad \text{and} \quad K = k_{rw} * K_{sat} \quad (2)$$

where

K = permeability ( $\text{cm}^2$ ) or hydraulic conductivity ( $\text{cm/s}$ )

$k_{rw}$  = relative permeability or hydraulic conductivity

$K_{sat}$  = permeability ( $\text{cm}^2$ ) or saturated hydraulic conductivity ( $\text{cm/s}$ )

$S_w$  and m are defined as before.

Usually the m parameter determined from the saturation-capillary pressure relationship is also used in the Mualem relative hydraulic conductivity equation, but using a value of 1.9 (instead of  $1 - 1/n$  or 0.778) provided a closer approximation of the linear relationship between saturation and relative hydraulic conductivity assumed in Magnuson (1993) and Schafer et al. (1997).

## 2.1.2 Model Calibration and Validation

Several hydrologic investigations have provided substantial information about the hydraulic characteristics of the vadose zone, but, as stated previously, insufficient data exist to calibrate a vadose model. To ensure comparability with previous efforts and investigations, the screening model and results (Martian 2000) provided a means of validating the STOMP model and modeling approach by comparison. A two-dimensional model using similar input as the screening model was constructed using STOMP. The STOMP model simulated the screening model described as possessing an attenuation barrier. To account for the side slopes of the ICDF landfill, the recharge was proportioned according to the increase in the ICDF area at ground surface. The screening model identified square bottom dimensions of 125 m, and square ground surface dimensions of 155 m. Thus, recharge through the ICDF in the STOMP model was proportioned by a factor of 1.5376 ( $155 \text{ m} \times 155 \text{ m} / [125 \text{ m} \times 125 \text{ m}]$ ). Table 2 shows the comparison of the STOMP and the screening model results. The STOMP results compared well to the screening model results; in general, peak concentrations and arrival times were within 10%. This comparison indicates good correlation of both travel times and groundwater contaminant concentrations between the two simulations for the contaminants identified. As a further measure of validation, an analogous model using the semianalytical GWSCREEN was constructed and run for I-129. Results of the GWSCREEN model (discussed in Appendix A) were about 30% less than the STOMP results, which was considered acceptable given the conservative STOMP results and the differences in the two models' methodology.

Table 2. Comparison of STOMP and screening model results (EDF-ER-170 [Martian 2000]) with attenuation barrier at ICDF bounding inventory values<sup>a</sup>.

Contaminant		STOMP Results				Screening Model Results	
		Using Approximated TETRAD Brooks-Corey Basalt Saturation-Capillary Pressure Relationship		Using van Genuchten Basalt Saturation-Capillary Pressure Relationship		Using TETRAD Brooks-Corey Basalt Saturation-Capillary Pressure Relationship	
		Peak Concentration (pCi/L)	Peak Arrival Time (Years)	Peak Concentration (pCi/L)	Peak Arrival Time (Years)	Peak Concentration (pCi/L)	Peak Arrival Time (Years)
Recharge Rate 1.0 cm/yr	I-129	65.4	561	63.8	581	64.8	600
	Np-237	57.4	14,348	56.1	15,348	59.5	15,450
	Tc-99	19,150	813	18,634	834	20,500	800
	I-129	7.05	4,080	6.93	5,010	7.08	5,400
	Np-237	5.92	125,802	5.82	125,802	4.99	>100,000
	Tc-99	2,034	7,048	1,991	7,248	2,220	8,400

a. Model results for screening assessment point located 20 m downgradient from the edge of waste.

One complexity encountered in matching the screening model output was imitating in STOMP the hydraulic characteristics of the basalt layers in the screening model (TETRAD). The Brooks-Corey equation algorithm used in TETRAD to describe the basalt layers' moisture content (saturation)-capillary pressure relationship (and the assumed linear relationship between saturation and relative hydraulic conductivity) appears to be proprietary, and is not directly available in STOMP. However, the algorithm can be approximated in STOMP by calculating and tabulating saturation-capillary pressure values and interpolating between tabulated values. The results presented in Table 2 show that changing the saturation-capillary pressure relationship from the version of the Brooks-Corey equation in TETRAD to the van Genuchten equation (van Genuchten et al. 1991) resulted in little change in the peak concentration or peak arrival time.

Because the van Genuchten saturation-capillary pressure relationship is more widely available for vadose modeling than the version of the Brooks-Corey equation used in TETRAD (e.g., neither HYDRUS or STOMP include it, nor is that version of the Brooks-Corey equation contained in EPA/600/2-91/065 [1991]), the fate and transport simulations reported here used the van Genuchten equation to simulate the basalt moisture content (saturation)-capillary pressure relationship. The SRPA basalt and vadose basalt van Genuchten curve fit parameters were determined by approximating the saturation-capillary relationship shown in Figure 21 of Schafer et al. (1997) with Van Genuchten saturation-capillary pressure curves (Figure 1).

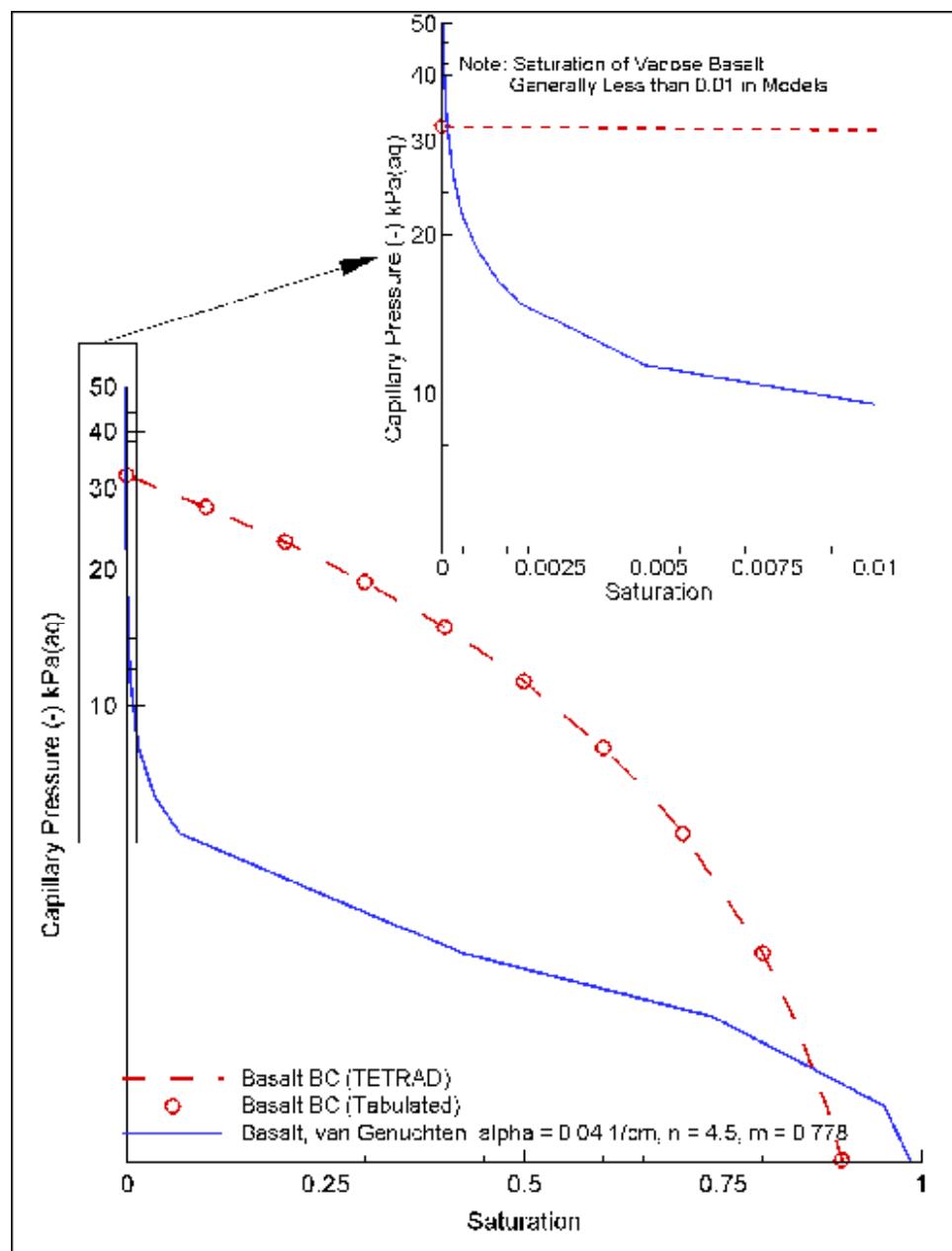


Figure 1. Comparison of the van Genuchten moisture content (saturation)-capillary pressure relationship to the TETRAD Brooks-Corey equation.

### 2.1.3 Model Construction

Figure 2 shows the revised conceptual model used to develop the numerical model grid (shown in Figure 3) and establish the model layers. Similar to the screening model, the numerical model only accounts for the vertical transport of moisture and contaminants in the vadose zone, and assumes that there is no influence from the wastewater disposal ponds or the Big Lost River. The influence of the Big Lost River on contaminant transport to the SRPA was previously analyzed in site modeling performed for development of the conceptual design report (Martian 2000). It was determined to have the

effect of decreasing contaminant time of travel to the aquifer but also decreasing the concentrations due to dilution.

The length dimension of the ICDF landfill facility in the numerical model was determined from preliminary construction drawings (DOE-ID 2002) to be about 160 m in the direction parallel to groundwater flow. In the direction perpendicular to flow, the length dimension is about 194 m. The side slope of the landfill is ~3:1, so for the estimated waste volume (510,000 yd<sup>3</sup> or 389,923 m<sup>3</sup>), the height of the trapezoidal waste volume is about 9.3 m. The slope of the sides increases the area at the top of the waste area to about 215.8 m by 249.8 m. Therefore, the contaminant transport portion of the modeling increased the specified recharge rate by a factor of ~ 1.74:1 (215.8 m × 249.8 m/[160 m × 194 m]). To maintain waste volume balance in the numerical model, the simulated waste height was adjusted to 12.56 m (389,923 m<sup>3</sup> / [160 m × 194 m] ≈ 12.56 m). The model domain represented a vertical cross-section of the ICDF waste area and operations area, the clay liner, and the vadose zone. The groundwater domain included 58 m to the edge of the surface barrier and 20 m to the assessment point within the upper portion (approximately 5 m) of the SRPA.

Tables 3 and 4 present the soil hydraulic and contaminant transport parameters of the different layers used in the model and the source of the information. In general, parameters developed in previous models (e.g., Schafer et al. 1997; Martian 2000) were carried forward except where new data were available. The site geotechnical report (DOE-ID 2000) and recent drilling during November 2001 provided substantial new information and data about the lower alluvium unit present near the ICDF site, and the design specifications provided new information regarding the clay, operations layer, and waste layer. For all layers, the saturated moisture content was assumed to equal the porosity. Synthetic materials that are part of the liner design (e.g., polymer membranes, etc.) were not included in the model stratigraphy.

The hydrologic and contaminant fate and transport modeling was conducted in two steps (see Appendix E for STOMP input parameters). The first step involved inputting background hydrologic boundary conditions and calculating the steady-state solution for water content and capillary pressure. The upper boundary received constant infiltration equal to 0.01 m/yr (1 cm/yr), and the sides of the model in the vadose zone allowed no flow or contaminant transport to occur across those boundaries. The upgradient aquifer boundary received a constant flux of 0.06 m per day (m/day), which equates to a flow velocity of 1 m/day. The downgradient aquifer boundary was fixed to a constant hydraulic head such that the head at the assessment point equaled approximately 5 m. The background hydraulic boundary conditions were comparable to those presented in Martian (2000). In the second step, the output solution of the steady-state simulation was used as the input starting condition for the contaminant transport simulations. Figure 4 shows the residual moisture content of the STOMP simulation.

Table 3. Summary of soil properties and moisture content (saturation)-aqueous pressure relationship curve fit parameters.

Model Layer Type	Saturated Moisture Content	Residual Moisture Content	Curve Fit Parameter α (1/m)	Curve Fit Parameter n	Curve Fit Parameter m
SRPA basalt <sup>a</sup>	0.06	0.0002	4.0	4.50	0.778 / 1.9
Basalt	0.05	0.0002	4.0	4.50	0.778 / 1.9
Interbed <sup>b</sup>	0.487	0.142	1.066	1.523	0.343
Alluvium <sup>c</sup>	0.424 [0.487] <sup>d</sup>	0.142	0.595 [1.066] <sup>d</sup>	1.09 [1.523] <sup>d</sup>	0.083 [0.343] <sup>d</sup>
Clay <sup>e</sup>	0.39	0.07	0.800	1.108	0.097

Table 3. (continued).

Model Layer Type	Saturated Moisture Content	Residual Moisture Content	Curve Fit Parameter $\alpha$ (1/m)	Curve Fit Parameter n	Curve Fit Parameter m
	[0.4] <sup>d</sup>				
Operations layer <sup>f</sup>	0.275 [0.487] <sup>d</sup>	0.083 [0.142] <sup>d</sup>	1.066	1.523	0.343
Waste <sup>f</sup>	0.266 [0.487] <sup>d</sup>	0.072 [0.142] <sup>d</sup>	1.066	1.523	0.343

a. Basalt curve fit parameters moisture content parameters are reported in Schafer et al. 1997, and curve fit parameters are estimated from moisture content/pressure relationship in Shafer et al. 1997. Basalt parameter m is 0.778 for saturation-capillary pressure relationship, and 1.9 for saturation-relative hydraulic conductivity relationship.

b. Interbed moisture content and curve fit parameters are reported in Schafer et al. 1997.

c. Alluvium parameters are determined from site geotechnical report (DOE-ID 2000), except the residual moisture content (no data reported).

d. Values used in the screening model (Martian 2000) are shown in brackets where different.

e. Clay saturated moisture content is based on design specifications; residual moisture content and curve fit parameters are reported in EDF-ER-170 (Martian 2000).

f. Operations and waste layers saturated and residual moisture content parameters are based on design specifications; curve fit parameters are reported in EDF-ER-170 (Martian 2000). These moisture layer parameters differ due to different compaction levels.

Table 4. Summary of soil hydraulic and contaminant transport properties.

Model Layer Type	Bulk Density <sup>a</sup> (kg/m <sup>3</sup> )	Saturated Hydraulic Conductivity <sup>b</sup> (cm/s)	Vertical Dispersivity <sup>c</sup> (m)	Longitudinal Dispersivity <sup>c</sup> (m)	Transverse Dispersivity <sup>c</sup> (m)
SRPA basalt	2491	2.6e - 04 <sup>d</sup>	6	3	
Basalt	2518	2.6e - 04 <sup>d</sup>	5	0	
Interbed	1359	6.7e - 05	5	0	
Alluvium	1526	6.7e - 08	5	0	
Clay	1586	1e - 07	5	0	
Operations layer	1922	1e - 04	5	0	
Waste	1946	1e - 03	5	0	

a. Bulk density is determined from the saturated moisture content and assumed particle solid density of 2,650 kg/m<sup>3</sup>, except for alluvium with bulk density values reported in the site geotechnical report (DOE-ID 2000), and the clay with a design particle solid density of 2,600 kg/m<sup>3</sup>.

b. Saturated hydraulic conductivity values are reported in EDF-ER-170 (Martian 2000), except for alluvium with values reported in DOE-ID 2000, and basalt with values reported in Schafer et al. 1997.

c. Longitudinal and transverse dispersivity values are reported in EDF-ER-170 (Martian 2000).

d. Basalt saturated horizontal hydraulic conductivity = 7.7e-02 cm/sec.

## ENGINEERING DESIGN FILE

431.02  
01/30/2003  
Rev. 11

EDF-ER-275  
Revision 3  
Page 18 of 228

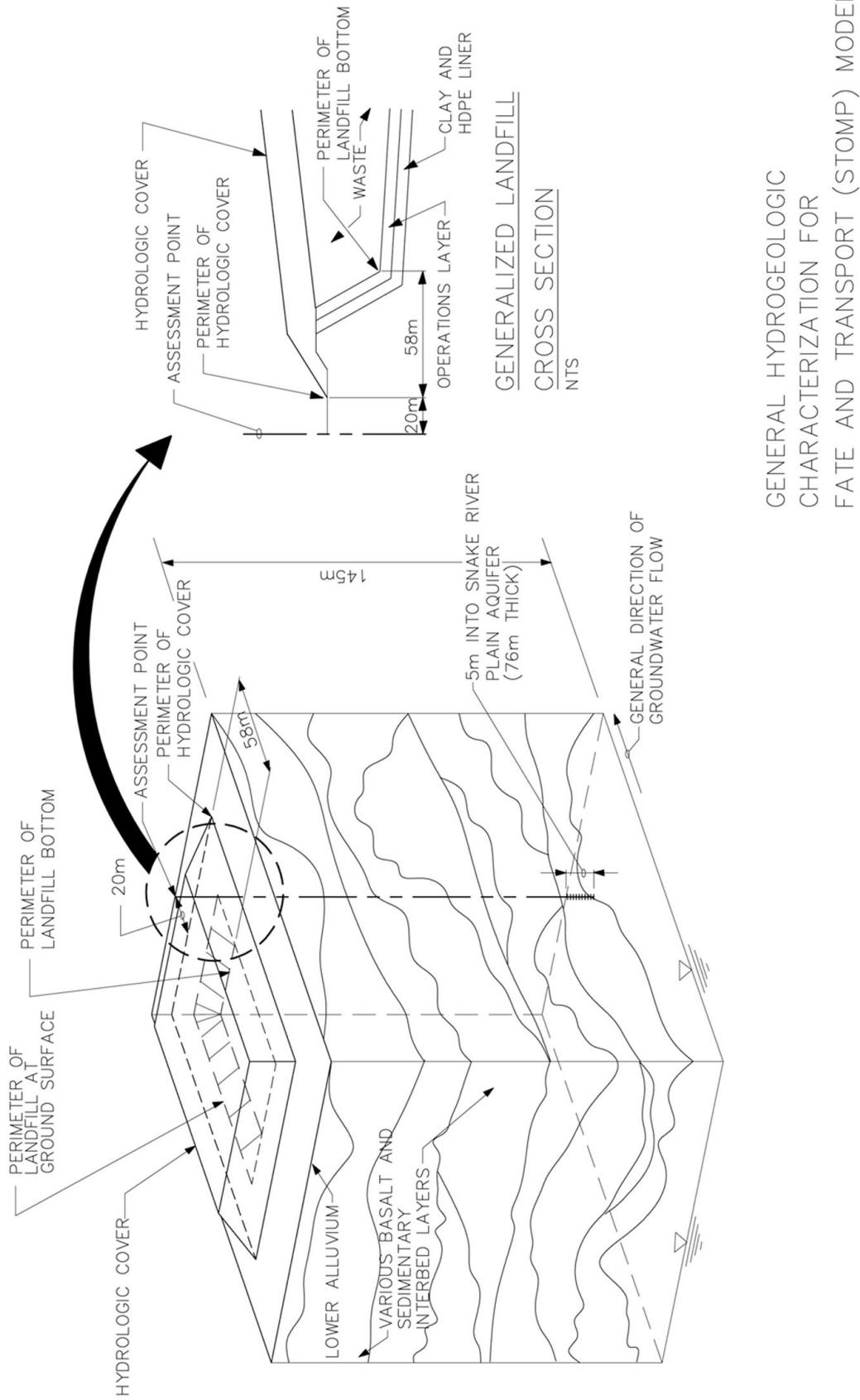


Figure 2. Conceptual model of ICDF vertical profile.

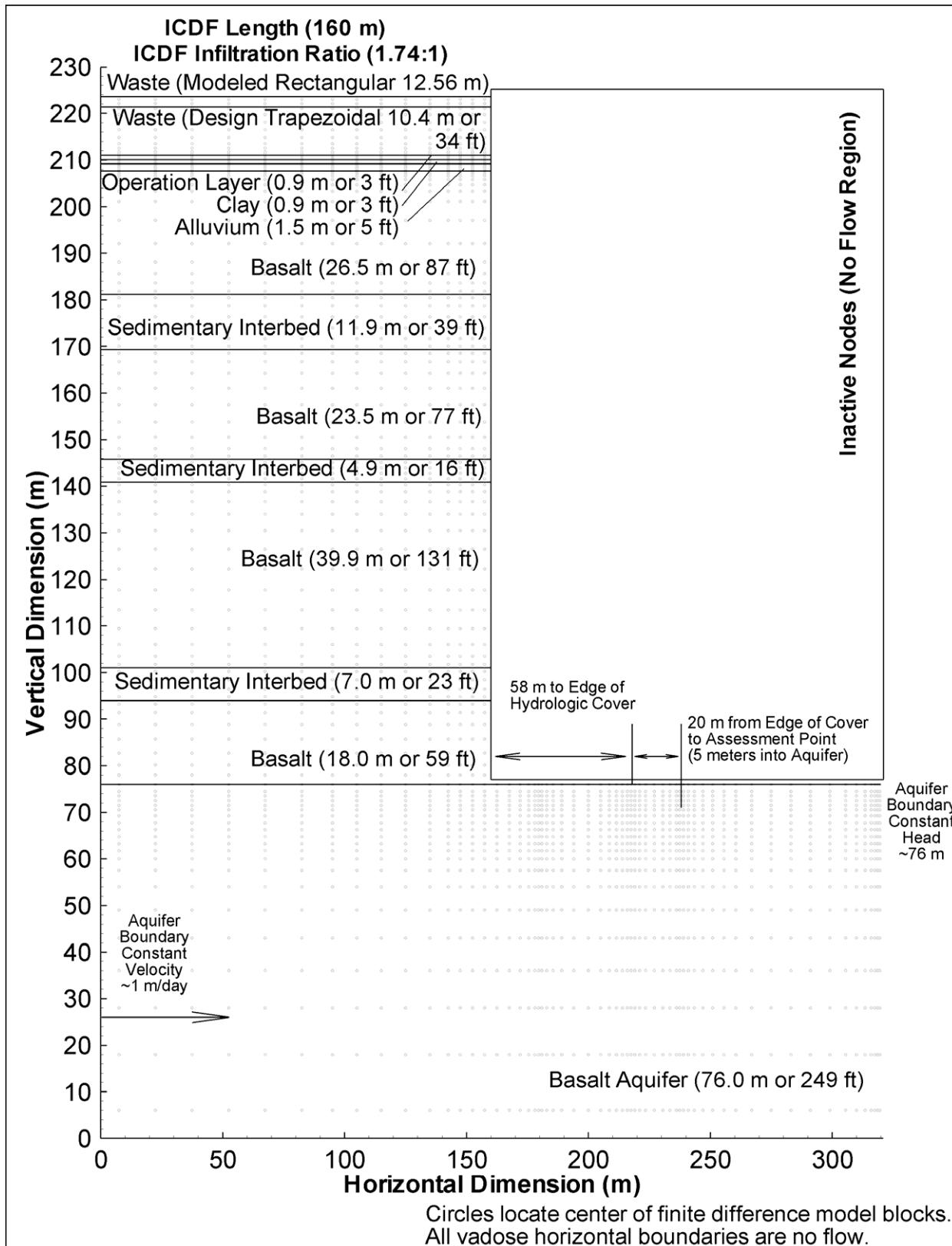


Figure 3. Numerical model grid and boundary conditions of ICDF vertical profile.

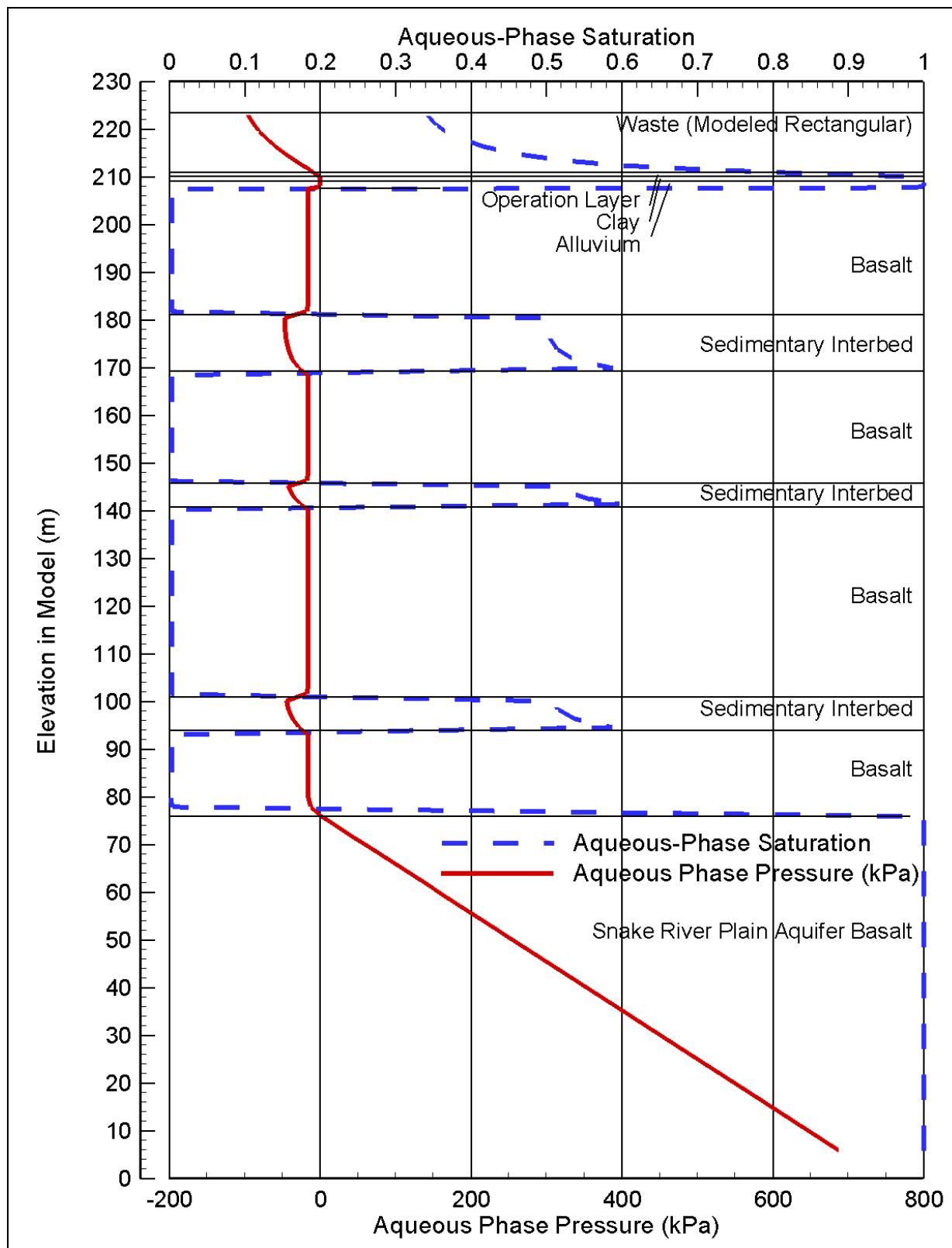


Figure 4. Residual moisture and capillary pressure initial conditions for transport simulations using STOMP.

## 2.1.4 Model Output

Contaminant attenuation factors for eight surrogates representing the range of expected distribution coefficients were calculated in the following manner. The waste layers of the model were assigned unit contaminant concentrations (1 unit of contaminant per kilogram of waste soil). The waste layer contaminant concentrations were assumed to occur instantaneously, but depleted over time as contaminant mass exited the waste layers. Using unit contaminant concentrations in the waste soil allows the resulting aquifer concentrations at the assessment point (units/L) to be scaled according to the actual waste concentrations based on the design inventory of the ICDF. For example, if 1 unit of contaminant per kilogram of waste soil resulted in a peak concentration of 0.005 units/L of contaminant at the assessment point, then an ICDF inventory of 3 mg contaminant per kilogram of waste soil would result in a concentration of 0.015 milligram per liter (mg/L) at the assessment point. Conversely, acceptable concentration limits in the ICDF waste may be back-calculated by dividing the allowable concentration in the aquifer by the resulting aquifer concentration from the model. Radioactive and non-radioactive decay were not included in this step of the modeling. No limitations to contaminant solubility were imposed by the model.

To determine the actual peak concentration and resulting attenuation factor at the assessment point (according to the model results), the scaled concentration at each time step in the model simulation result is multiplied by the radioactive or environmental decay rate. An example of this method is shown in Figure 5, which shows the concentration of surrogate 4 and four uranium isotopes at the assessment point at the design recharge/infiltration rate. Uranium-238, with a half life 4.47E + 09 years, experiences very little decay during the simulation period, and thus the arrival time is essentially equivalent to that of the undecayed surrogate (8.52E + 05 years). The peak concentration is essentially equivalent to the product of design inventory concentration multiplied by the peak contaminant concentration ratio ( $1.95E + 03$  pCi/kg \*  $3.43E - 06$  pCi/L per pCi/kg = 6.69 pCi/L). Shorter-lived radionuclides tend to peak earlier but at much lower concentrations than non-decaying or longer-lived isotopes. Uranium-234, with a half-life of  $2.45E + 05$  years, peaks in concentration in approximately  $5.23E + 05$  years, but at a concentration ( $3.26E - 03$  pCi/L) almost an order of magnitude less than if no decay occurred ( $6.03E + 03$  pCi/kg \*  $3.43E - 06$  pCi/L per pCi/kg =  $2.07E - 02$  pCi/L). Contaminant transport was modeled at two recharge/infiltration rates (0.01 and 0.0001 m per year [m/yr]) to provide a sensitivity analysis on the range of expected results on the basis of barrier performance and having no barrier.

## 2.2 Model Results

The STOMP simulations were extended to a maximum elapsed time of 1,000,000 years. The results show that no undecayed surrogate peaks reached the assessment point in less than 30,000 years at the maximum design infiltration rate of 0.0001 m/yr (based on the results of hydrologic modeling of the final cover design for the ICDF). Only surrogates with weighted vadose distribution coefficients less than or equal to that of Surrogate 4 will peak at the assessment point in less than 1 million years at the maximum design infiltration rate. Radionuclide contaminant concentrations may peak at the assessment point before the arrival of the undecayed surrogate peak. However, the peak concentration for these radionuclides tends to be orders of magnitude less than the peak concentration of the undecayed surrogate. The results indicate that as long as the surface barrier continues to function, almost any radionuclide with a half life less than 1,000 years will not reach the assessment point before decaying to undetectable quantities.

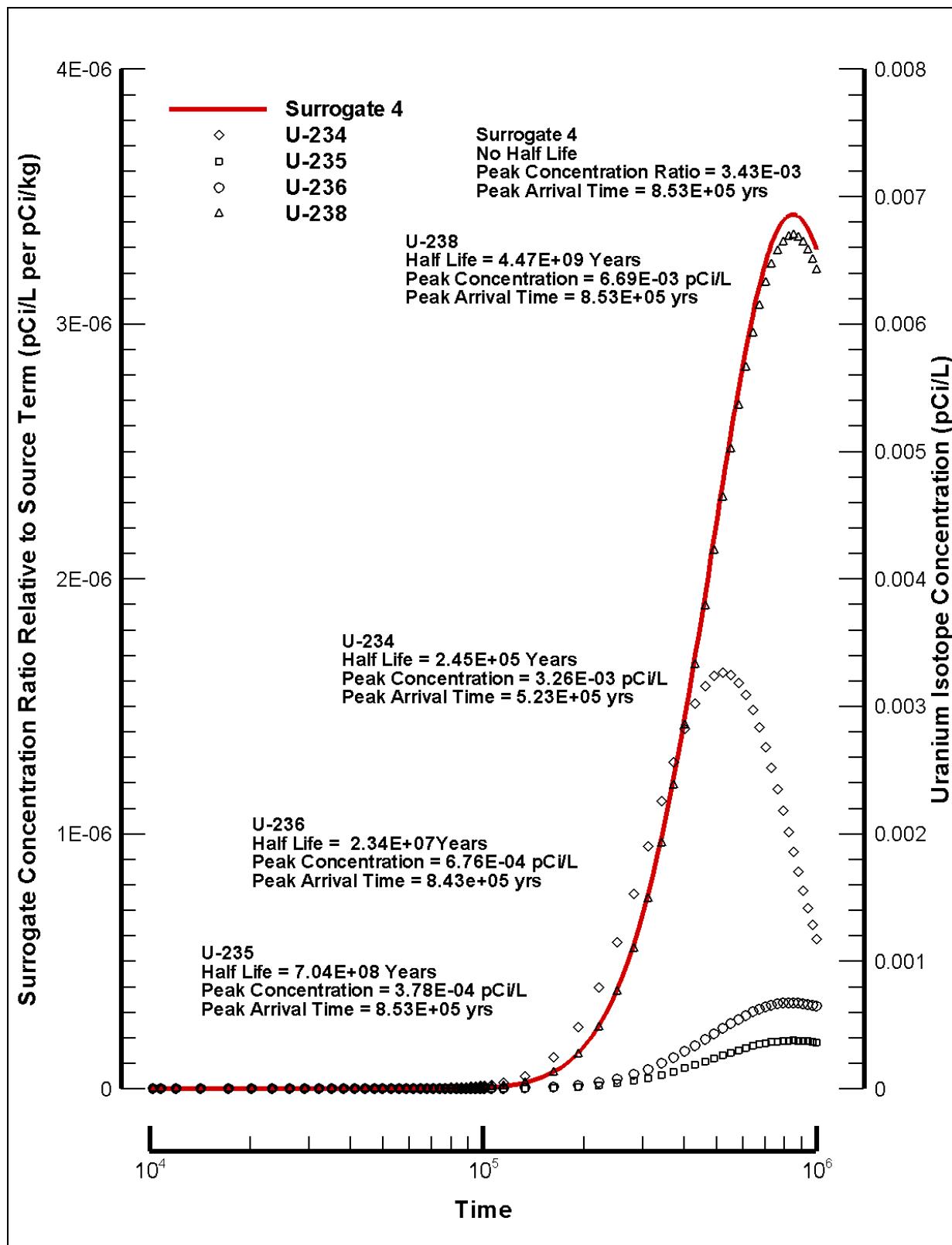


Figure 5. Example contaminant arrival curves at the assessment point for Surrogate 4 and three uranium isotopes at the design recharge/infiltration rate.

The peak dilution/attenuation factors shown in Table 5 for the design infiltration/recharge rate. These peak factors indicate that, for Surrogate 1, the ratio of the peak groundwater concentration to a unit concentration is 1.20E - 04. This means that for a non-decaying contaminant, the peak groundwater concentration (in mg/L or pCi/L) at the assessment point can be calculated by multiplying the dilution/attenuation factor (1.20E - 04 1/L per 1/kg) by the soil concentration in the ICDF in mg/kg or pCi/kg. For example, tritium (H-3) is simulated using Surrogate 1. The peak dilution/attenuation factor for Surrogate 1 is 1.20E-04 units/Liter per unit/Kilogram soil (or 1.20E-04 Kg/L). If the waste soil contains 100 pCi tritium /Kilogram, then the estimated peak undecayed groundwater concentration at the assessment point would be as follows:

$$100 \text{ pCi/Kg} * 1.20\text{E-}04 \text{ Kg/L} = 1.20\text{E-}02 \text{ pCi tritium/L}$$

Iodine-129 is an example of a constituent simulated using Surrogate 2. The peak dilution/attenuation factor for Surrogate 2 is 9.91E-05 units/Liter per unit/Kilogram soil (or 9.91E-05 Kg/L). If the waste soil contains 20 pCi I-129/Kilogram, then the estimated peak undecayed groundwater concentration at the assessment point would be as follows:

$$20 \text{ pCi/Kg} * 9.91\text{E-}05 \text{ Kg/L} = 1.98\text{E-}03 \text{ pCi I-129/L}$$

The peak concentration of the most mobile non-decaying constituents is expected to occur at least 32,605 years after placement of the waste. Tritium is an example of a radionuclide simulated by Surrogate 1. Because the half-life of tritium is 12.3 years, the peak concentration of that contaminant occurs closer to the contaminant's first arrival in groundwater (70 years, as indicated in the STOMP output file) than the arrival of the undecayed peak. However, the tritium peak dilution/attenuation factor is less than the surrogate peak dilution/attenuation factor by several orders of magnitude.

Table 5. Results of surrogate contaminant transport simulations and example radionuclide dilution/attenuation factors and peak arrival times at maximum design recharge rate.

Contaminant	Peak Dilution/Attenuation Factor (1/L per 1/kg soil)	Recharge Rate 0.0001 m/yr	
		Peak Dilution/Attenuation Factor	Arrival Time (yrs)
Surrogate 1	1.20E - 04		32,605
Surrogate 2	9.91E - 05		36,605
Surrogate 3	6.33E - 05		59,007
Surrogate 4	3.43E - 06		895,312
Surrogate 5	2.97E - 06		1,000,000
Surrogate 6	8.26E - 07		1,000,000
Surrogate 7	4.88E - 08		1,000,000
Surrogate 8	5.50E - 17		1,000,000

Based on the surrogate model results, each constituent identified in the design inventory is modeled using the representative surrogate dilution/attenuation factors (see Appendix B). The appendix continues on by evaluating the constituent concentrations in groundwater as compared with the RAOs. The methodology and results of the process are presented in Appendix B. The calculation for risk-based concentrations (RBC) is presented in Appendix C.

Table 6 presents the results of the contaminant transport modeling of peak arrival time and peak concentration for the two simulated recharge rates. By using the dilution/attenuation factor derived from the simulations and the design inventory concentrations, the estimated assessment point peak concentration of the COC can be calculated for all COCs. Table 6 contains the results of a subset of the total list of COCs.

Table 6. Results of selected contaminant transport simulations at maximum design recharge rate (0.0001 m/yr) scaled to ICDF inventory.

Constituent		Half-Life (years)	Design Inventory Concentration ( $C_{DI}$ ) (pCi/kg or mg/kg)	Peak Concentration (pCi/L or mg/L)	Peak Concentration Arrival Time (years)
H 3	Surrogate 1	1.24E + 01	4.96E + 04	2.15E - 08	1.00E + 02
Sulfate	Surrogate 1	NA	2.05E + 01	2.46E - 03	3.13E + 04
Sulfide	Surrogate 1	NA	7.59E + 02	9.10E - 02	3.13E + 04
Tributylphosphate	Surrogate 1	1.16E + 00	3.64E - 01	4.36E - 05	3.03E + 04
I129	Surrogate 2	1.57E + 07	1.30E + 03	1.28E - 01	3.33E + 04
Benzene	Surrogate 2	1.00E + 00	6.03E - 01	5.66E-25	5.84E + 01
Toluene	Surrogate 2	4.20E - 02	9.82E - 01	8.12E-190	2.76E + 01
Tc 99	Surrogate 3	2.13E + 05	5.76E + 03	3.04E - 01	5.40E + 04
Xylene (total)	Surrogate 3	7.12E - 02	3.45E + 00	2.21E-50	5.84E + 01
Boron	Surrogate 3	NA	1.85E + 02	1.17E - 02	5.80E + 04
U234	Surrogate 4	2.45E + 05	6.03E + 03	3.26E - 03	5.13E + 05
U235	Surrogate 4	7.04E + 08	1.10E + 02	3.78E - 04	8.43E + 05
U236	Surrogate 4	2.34E + 07	2.02E + 02	6.76E - 04	8.33E + 05
U238	Surrogate 4	4.47E + 09	1.95E + 03	6.69E - 03	8.33E + 05
Np237	Surrogate 5	2.14E + 06	6.43E + 02	1.38E - 03	9.13E + 05
Dibenzofuran	Surrogate 5	4.79E - 02	3.24E - 01	0.00E + 00	NA
Molybdenum	Surrogate 5	NA	1.02E + 01	3.02E - 05	1.00E + 06
K-40	Surrogate 5	1.28E + 09	1.92E + 03	5.69E - 03	1.00E + 06
Sr90	Surrogate 6	2.91E + 01	2.29E + 07	0.00E + 00	NA
Cadmium	Surrogate 6	NA	3.59E + 00	2.96E - 06	1.00E + 06
Co-60	Surrogate 6	5.27E + 00	1.93E + 05	0.00E + 00	NA
Cobalt	Surrogate 6	NA	6.04E + 00	4.99E - 06	1.00E + 06
Sodium	Surrogate 7	NA	2.11E + 02	1.03E - 05	1.00E + 06
Pu238	Surrogate 7	8.77E + 01	2.33E + 05	1.05E - 204	5.60E + 04
Pu239	Surrogate 7	2.41E + 04	6.66E + 03	2.90E - 10	2.43E + 05
Pu241	Surrogate 7	1.44E + 01	6.39E + 04	0.00E + 00	NA
Lead	Surrogate 7	NA	5.76E + 01	2.81E - 06	1.00E + 06
Aluminum	Surrogate 7	NA	7.08E + 03	3.45E - 04	1.00E + 06
Ra226	Surrogate 7	1.60E + 03	4.74E + 02	1.00E - 25	5.60E + 04

TTable 6 (continued).

Constituent		Half-Life (years)	Design Inventory Concentration ( $C_{DI}$ ) (pCi/kg or mg/kg)	Peak Concentration (pCi/L or mg/L)	Peak Concentration Arrival Time (years)
Aroclor-1260	Surrogate 8	7.00E + 00	7.21E - 01	0.00E + 00	NA
Am241	Surrogate 8	4.32E + 02	2.38E + 04	0.00E + 00	NA
Eu152	Surrogate 8	1.33E + 01	9.68E + 05	0.00E + 00	NA
Eu154	Surrogate 8	8.80E + 00	8.21E + 05	0.00E + 00	NA
Chrysene	Surrogate 8	3.76E + 00	2.65E - 01	0.00E + 00	NA
Zirconium	Surrogate 8	NA	6.91E + 01	3.58E-15	1.00E + 06

NA – Not Available.

## 2.2.1 Radioactive Progeny

To address whether radioactive progeny contribute significantly to groundwater concentrations, the assumption was made that as a worst case the activities of the daughter products were equal to the activities of the initial inventories of the parents. The resulting daughter inventory was then added to the initial design activity of the daughter radionuclides and the potential effect of the total concentration on groundwater was evaluated. If the worst case is predicted not to affect groundwater there is no need to do further evaluations. Four decay sequences were evaluated on this basis, assuming that the daughter products had sufficient half-life to be transported from the landfill to the assessment point:

1. U-234 from the initial inventory of Pu-238
2. Am-241 from the initial inventory of Pu-241
3. Np-237 from the initial inventory of Pu-241
4. Np-237 from the initial inventory of Am-241.

Predicted peak concentrations of Np-237 and U-234 are significantly increased by assuming that the activity of the daughters are equal to the activity of the parent radionuclides in the inventory, but these peak concentrations are not expected to occur for more than 500,000 years. The Np-237 and its parent inventory, which shows a relatively high peak concentration, is not expected to reach the assessment point in any quantity for at least 17,000 years, and its groundwater concentration would not be predicted to exceed 1 pCi/L for at least 150,000 years. The U-234 and its parent inventory are not predicted to reach the assessment point in any quantity for at least 14,000 years, and the peak concentration is not predicted to occur until 523,000 years. The Am-241 decays too quickly to expect any quantity to reach the assessment point. While the radioactive decay process occurs, the daughter products would be transported from the source term, reducing the source term concentration and reducing the resulting groundwater concentration. As a result, it is not possible that future U-234 and Np-237 concentrations at the assessment point will be as high as those estimated by assuming that the activity of the daughters are equal to the activity of the parent radionuclides. Therefore, the daughter products are not considered to pose a future risk. Table 7 presents a summary of the results.

Table 7. Results of selected radioactive daughter product transport simulations at maximum design recharge rate scaled to ICDF inventory of all parents.

Isotope	Specific Activity	Design Inventory (Ci/g)	Design Inventory (kg)	Inventory with Progeny (Ci)	Inventory with Progeny pCi/kg	Peak DAF <sup>a</sup> (pCi/L per pCi/kg)	Peak Assessment Point Concentration (pCi/L)	Peak Assessment Point Concentration (pCi/L)	Assessment Point Concentration Arrival Time (Years)
Pu-238	1.71E + 01	7.97E - 03	1.37E + 02						
Pu-241	1.03E + 02	3.63E - 04	3.74E + 01						
Np-237	7.05E - 04	5.33E - 01	3.76E - 01	5.17E + 01	8.84E + 04	2.15E - 03	1.90E + 02	9.63E + 05	
Am-241	3.44E + 00	4.06E - 03	1.39E + 01	5.13E + 01	8.77E + 04	0	0	0	
U-234	6.24E - 03	5.65E - 01	3.53E + 00	1.40E + 02	2.39E + 05	5.41E - 07	1.30E - 01	5.23E + 05	

a. Dilution/attenuation factor (DAF).

## 2.2.2 Sensitivity Analysis

Additional modeling scenarios were conducted to evaluate some of the parameters that are expected to have the greatest effect on the results. The sensitivity analysis focused on I-129 because that contaminant is highly mobile, a long-lived radionuclide, and is present in the design inventory at sufficient quantity to potentially pose elevated risk. In addition to the two recharge rates, alternate assessment points and screen size, and different distribution coefficients were used to simulate the fate and transport of the I-129. The alternate assessment points were located at the edge of the surface barrier (approximately 58 m from the bottom of the landfill), and 100 m from the edge of the surface barrier (approximately 158 m from the bottom of the landfill). The alternate screen length was 15 m, which is a common water production well screen length. Two different sets of distribution coefficients for the I-129 were used: one with a Kd = 0.1 in the waste layer and 0 elsewhere except in the clay, and the second with a Kd = 0.1 mL/g in all of the waste, operations, and interbed layers, and 0 elsewhere except in the clay. All sets use Kd = 1 mL/g in the clay layer. The results show that the I-129 concentration is most sensitive to changes in the recharge rate. The other changes generally resulted in changes of less than 10% in the assessment point groundwater concentrations. The I-129 concentration does not appear to be strongly dependent on the location of the assessment point or screen length, especially when the time frame of the modeling is considered. Table 8 summarizes the results and includes the results of the design fate and transport simulations for the purpose of comparison.

Table 8. Results of selected radioactive daughter product transport simulations at maximum design recharge rate scaled to ICDF inventory of all parents.

Well Screen Length	Design Inventory Concentration = 1.30E + 03 pCi/kg	Recharge = 0.01 m/yr		Recharge = 0.0001 m/yr	
		Peak Undecayed DAF	Peak Concentration (pCi/L)	Peak Undecayed DAF	
				(Ci/L per Ci/kg)	Peak Concentration (pCi/L)
I-129o	5 m	Assessment Pt. 1	8.83E + 00	1.15E + 01	9.91E - 02
I-129o	5 m	Assessment Pt. 2	9.55E + 00	1.24E + 01	1.08E - 01
I-129o	5 m	Assessment Pt. 3	7.14E + 00	9.28E + 00	7.92E - 02

Table 8. (continued).

	Well Screen Length	Design Inventory Concentration = 1.30E + 03 pCi/kg	Recharge = 0.01 m/yr		Recharge = 0.0001 m/yr	
			Peak Undecayed DAF	Peak Concentration (pCi/L)	Peak Undecayed DAF (Ci/L per Ci/kg)	Peak Concentration (pCi/L)
I-129o	15 m	Assessment Pt. 1	8.48E + 00	1.10E + 01	9.49E - 02	1.23E - 01
I-129o	15 m	Assessment Pt. 2	9.10E + 00	1.18E + 01	1.02E - 01	1.33E - 01
I-129o	15 m	Assessment Pt. 3	6.96E + 00	9.05E + 00	7.72E - 02	1.00E - 01
I-129A	5 m	Assessment Pt. 1	8.13E + 00	1.06E + 01	9.09E - 02	1.18E - 01
I-129A	5 m	Assessment Pt. 2	8.80E + 00	1.14E + 01	9.89E - 02	1.29E - 01
I-129A	5 m	Assessment Pt. 3	6.57E + 00	8.54E + 00	7.27E - 02	9.45E - 02
I-129A	15 m	Assessment Pt. 1	7.81E + 00	1.02E + 01	8.71E - 02	1.13E - 01
I-129A	15 m	Assessment Pt. 2	8.37E + 00	1.09E + 01	9.38E - 02	1.22E - 01
I-129A	15 m	Assessment Pt. 3	6.41E + 00	8.34E + 00	7.08E - 02	9.21E - 02
I-129B	5 m	Assessment Pt. 1	6.84E + 00	8.89E + 00	7.72E - 02	1.00E - 01
I-129B	5 m	Assessment Pt. 2	7.40E + 00	9.61E + 00	8.40E - 02	1.09E - 01
I-129B	5 m	Assessment Pt. 3	5.53E + 00	7.18E + 00	6.17E - 02	8.02E - 02
I-129B	15 m	Assessment Pt. 1	6.56E + 00	8.53E + 00	7.40E - 02	9.62E - 02
I-129B	15 m	Assessment Pt. 2	7.04E + 00	9.15E + 00	7.97E - 02	1.04E - 01
I-129B	15 m	Assessment Pt. 3	5.39E + 00	7.01E + 00	6.02E - 02	7.82E - 02

I-129o: Kd = 1 mL/g in Clay, 0 elsewhere

I-129A: Kd = 1 mL/g in Clay, 0.1 mL/g in Waste, 0 elsewhere

I-129B: Kd = 1 mL/g in Clay, 0.1 mL/g in other non-Basalts, 0 elsewhere

Assessment Pt. 1 = 78 m from Waste (20 m from Edge of Cap)

Assessment Pt. 2 = 58 m from Waste (Edge of Cap)

Assessment Pt. 3 = 158 m from Waste (100 m from Edge of Cap).

### **2.2.3 Estimated Efficacy of Design Cover Recharge Reduction**

A comparison of the apparent efficacy of the design final cover for the ICDF at the estimated background recharge rate and at the design cover recharge rate was performed to estimate the risk reduction that may be provided by the final cover. To perform this assessment, the cumulative excess carcinogenic risk, cumulative hazard index (HI) for non-carcinogens, and the total alpha-emitting radionuclide concentrations in groundwater were calculated based on the fate and transport simulation described in the preceding sections.

The comparison was made by determining the peak risk, HI, and alpha-emitter concentration in groundwater during the 1,000-year design life of the final cover. The final cover could provide up to six orders of magnitude reduction in carcinogenic risk and HI, with greater than eight orders of magnitude reduction in the concentration of alpha emitters during the 1,000-year design life of the cover. The results of the comparison are shown in Table 9. The cumulative risk, HI, and alpha emitter concentration are shown in figures in Appendix D.

Table 9. Comparison of estimated carcinogenic risk, cumulative HI, and alpha-emitter concentration in groundwater during the 1,000-year design life at the ICDF at background recharge rate and design cover recharge rate.

Risk Factor	Units	Recharge = 0.01 m/yr	Recharge = 0.0001 m/yr
Hazard Index	Unitless	3.8E00	3.9E - 06
Excess Carcinogenic Risk	Unitless	3.7E - 05	1.0E - 11
Total Alpha Emitters	pCi/L	8.0E - 06	<1.0E - 14

### **3. CONCLUSIONS**

The fate and transport modeling conducted to support construction of the ICDF indicates that the landfill requires the surface barrier to limit recharge to meet groundwater RAOs. According to the results of hydrologic cover and the fate and transport modeling, the cover barrier is designed to prevent potentially elevated risk at the assessment point from occurring for thousands of years. A specific sensitivity analysis conducted on the fate and transport of I-129 indicated that the estimated peak concentration for the 1,000,000-yr simulation would be around 10 pCi/L at a recharge rate of 0.01 m/yr, but that the presence of the barrier reduces the estimated peak concentration by a factor of 100. Analysis of radioactive daughter products indicated that even if all of the design inventory parents were converted to Np-237, the peak concentration would not occur for over 950,000 years, and the concentration would not be expected to exceed 1 pCi/L for at least 150,000 years. No other daughter products are expected to pose a risk in the groundwater.

The design recharge rate expected to be provided by the final cover for the ICDF would provide approximately a six order-of-magnitude reduction in carcinogenic risk, non-carcinogenic HI, and concentration of alpha-emitting radionuclides over the 1,000-year design life of the final cover. This analysis indicates that the ICDF can be constructed and operated to not exceed the groundwater RAOs during the design life of the facility.

### **4. REFERENCES**

- DOE-ID, 2000, *Geotechnical Report for the Conceptual Design of the INEEL CERCLA Disposal Facility at Waste Area Group 3, Operable Unit 3-13*, DOE/ID-10812, Department of Energy Idaho Office Operations, Idaho Falls, Idaho.
- DOE-ID, 2002, *INEEL CERCLA Disposal Facility Remedial Design/Construction Work Plan*, DOE/ID-10848, Rev. 1, Appendix Z, "INEEL CERCLA Disposal Facility - Drawings," U.S. Department of Energy Idaho Operations Office, Idaho Falls, Idaho, May 2002.
- EDF-ER-264, 2001, "INEEL CERCLA Disposal Facility Design Inventory," Rev. A, Environmental Restoration Program, Idaho National Engineering and Environmental Laboratory, March 2001.
- EDF-ER-279, 2002, "Hydrologic Modeling of Final Cover," Rev. 2, Environmental Restoration Program, Idaho National Engineering and Environmental Laboratory, May 2002.
- Magnuson, S., 1993, *Simulation Study of Moisture Movement in Proposed Barriers for the Subsurface Disposal Area, INEEL*, EGG-WM-10974, Idaho National Engineering Laboratory, EG&G Idaho, Inc, Idaho Falls, Idaho.

Mann, F. M., C. T. Kincaid, and W. J. McMahon, 1999, *Computer Code Selection Criteria for Flow and Transport Code(s) to be Used in Vadose Zone Calculations for Environmental Analyses in the Hanford Site's Central Plateau*, HNF-5294, Fluor Daniel Northwest Inc., Richland, WA.

Martian, P., 2000, *Screening Model Results of a Mixed Low-Level Waste Disposal Facility Proposed for the Idaho National Engineering and Environmental Laboratory*, EDF-ER-170, INEEL 2000-00406, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

Nichols, W. E., M. Oostrom, and M. D. White, 2000, *STOMP Subsurface Transport Over Multiple Phases Application Guide Version 2.0*, PNNL-12028, Pacific Northwest National Laboratory, Richland, WA.

PNNL, 1996, *Subsurface Transport Over Multiple Phases Description "STOMP" Theory Guide*, PNNL-11217, Pacific Northwest National Laboratory, Richland, Washington.

PNNL, 2000, *Subsurface Transport Over Multiple Phases Description "STOMP" User's Guide*, PNNL-12034, Pacific Northwest National Laboratory, Richland, Washington.

Schafer, et al., 1997, *Comprehensive Remedial Investigation/Feasibility Study for the Idaho Chemical Processing Plant OU 3-13 at the INEEL – Part A, RI/BRA Report, Appendix F*, DOE/ID-10534, U.S. Department of Energy Idaho Operations Office, Idaho Falls, Idaho.

Van Genuchten, M. Th., F. J. Leij, and S. R. Yates, 1991, *The RETC Code for Quantifying the Hydraulic Functions of Unsaturated Soils*, EPA/600/2-91/0651, United States Environmental Protection Agency, Office of Research and Development, Washington, DC.

431.02  
01/30/2003  
Rev. 11

**ENGINEERING DESIGN FILE**

EDF-ER-275  
Revision 3  
Page 30 of 228

This page intentionally left blank.

431.02  
01/30/2003  
Rev. 11

**ENGINEERING DESIGN FILE**

EDF-ER-275  
Revision 3  
Page 31 of 228

## **Appendix A**

### **Verification of STOMP Model Numerical Results for the Design of the ICDF**

431.02  
01/30/2003  
Rev. 11

**ENGINEERING DESIGN FILE**

EDF-ER-275  
Revision 3  
Page 32 of 228

This page intentionally left blank.

## Appendix A

# Verification of STOMP Model Numerical Results for the Design of the ICDF

### A.1 INTRODUCTION

The purpose of this appendix is to verify the numerical simulation accuracy of the fate and transport model results for the (ICDF). The verification simulations were performed for I-129 because this was the primary contaminant of concern identified in the ICDF flow and transport modeling.

The ICDF fate and transport modeling effort used the Subsurface Transport Over Multiple Phases (STOMP) version 2.0 finite difference code developed by Pacific Northwest National Laboratory (PNNL) to conduct the simulations. A description of the STOMP code is found in the Theory Guide (PNNL 1996) and the User's Guide (PNNL 2000). This code was selected over simpler codes for its ability to simulate flow and transport through the hydraulically complex Idaho National Engineering and Environmental Laboratory (INEEL) unsaturated zone. In particular, the INEEL unsaturated zone consists of engineered barrier layers under the waste and alternating basalt and interbed layers down to the aquifer. Each of the sediment and rock layers has dramatically different hydraulic and transport characteristics. This heterogeneity is difficult for numerical models to accurately simulate. STOMP has been shown to have this capability.

Because the responsible managers are not necessarily familiar with the STOMP model or modelers, verification simulations were performed using GWSCREEN Version 2.5a. GWSCREEN version 2.5 is documented in Rood, 1999. GWSCREEN is one of the primary subsurface transport codes used at the INEEL for *Comprehensive Environmental Response, Compensation, and Liability Act* and Performance Assessment related simulations. GWSCREEN is readily available and has been used by a number of the regulators responsible for approval of the ICDF construction. GWSCREEN is much easier to use than STOMP so that the chances of user error are reduced. In addition, the semi-analytical solution contains little numerical error providing a reliable solution for verification of the STOMP results.

Although GWSCREEN cannot accurately simulate complex flow through the heterogeneity of the INEEL unsaturated zone, approximations were made to develop a conceptual model in which transport is essentially equivalent to the STOMP conceptual model. This is possible primarily because steady state flow dominates STOMP flow system and the transport time through basalt in the unsaturated zone is insignificant compared to unsaturated zone transport through the other layers.

The I-129 fate and transport verification simulations were performed using GWSCREEN together with a two-compartment source term model as described in Section 2.1.

An underlying assumption of the two-compartment model is that contaminants are leached from the waste using a first order leaching function, then transported into the clay layer, and then leached from the clay layer to the unsaturated zone. This two-compartment model was created in Microsoft Excel and the resulting flux imported into GWSCREEN as a user defined discrete source release function to the unsaturated zone. This allows the modelers to account for transport through a clay layer with a different Kd value and different hydraulic characteristics than the waste or the interbeds. GWSCREEN's built in source term is limited to a waste volume and single unsaturated layer.

## A.2 CONCEPTUAL MODELS

The conceptual model and numerical discretization used for the ICDF design fate and transport modeling is shown in Figure A-1. Flow results from the STOMP simulation are shown in Figure A-2. Figures A-3 and A-4 show the conceptual model used for the GWSCREEN simulations and the two-compartment model used to simulate separately the waste and a clay layer. Important assumptions and differences are listed below.

- For the validation simulations, the infiltration rate is assumed to be 0.01 m/year at the top of the ICDF, which corresponds to the assumed natural background infiltration rate in INEEL soils. However, the area of the top of the waste facility has an area 74% larger than the area of the bottom of the facility. Therefore, the infiltration rates listed in the body of this flow and transport report are increased by 74% for all of the simulations. Consequently, the validation simulations are performed for an infiltration rate of 0.0174 m/year, to be consistent with the ICDF design simulations.
- The initial water pressures and water saturations are calculated in STOMP assuming a steady state infiltration rate of 0.01 m/year. When the cover is placed over the waste, the infiltration rate is changed to correspond to steady state infiltration predicted to move through the cover and funneled down through the ICDF.
- In the STOMP model, there is a transient flow period when the system adjusts from the initial conditions based on a 0.01 cm/year infiltration rate to the rate simulated for the facility. For the verification simulations the pressures and saturation will increase, as the infiltration rate is increased from 0.01 m/year to 0.0174 m/year. However, for the design infiltration rate of 0.000174 m/year (1.74 times 0.1 mm/year), the pressure and saturation will significantly decrease. After a relatively short period of time, the system equilibrates to the new infiltration rate and steady state flow continues to the end of the simulation.
- The STOMP model simulates the water transport through the different layers in the unsaturated zone. The GWSCREEN model assumes instantaneous transport of water and contaminants through the unsaturated zone basalts. Therefore, for the GWSCREEN simulation, the sediment and interbed layers below the waste are simulated as one homogeneous layer with a thickness equal to the sum of the layers.
- The receptor point is assumed to be 78 m from the downgradient edge of the waste, which is 20 m from the downgradient edge of the cover. For the GWSCREEN input file, the assessment location is input from the middle of the ICDF. Since the ICDF has a bottom length of 160 m, the GWSCREEN distance to the assessment point is 158 m.
- The saturation in the waste area is non-uniform, increasing with depth. STOMP simulates this variation in moisture content but for GWSCREEN, an average value must be assumed. This will have some affect on the contaminant releases from the waste to the layers below. Therefore, the GWSCREEN simulation results are not expected to exactly reproduce the STOMP results.

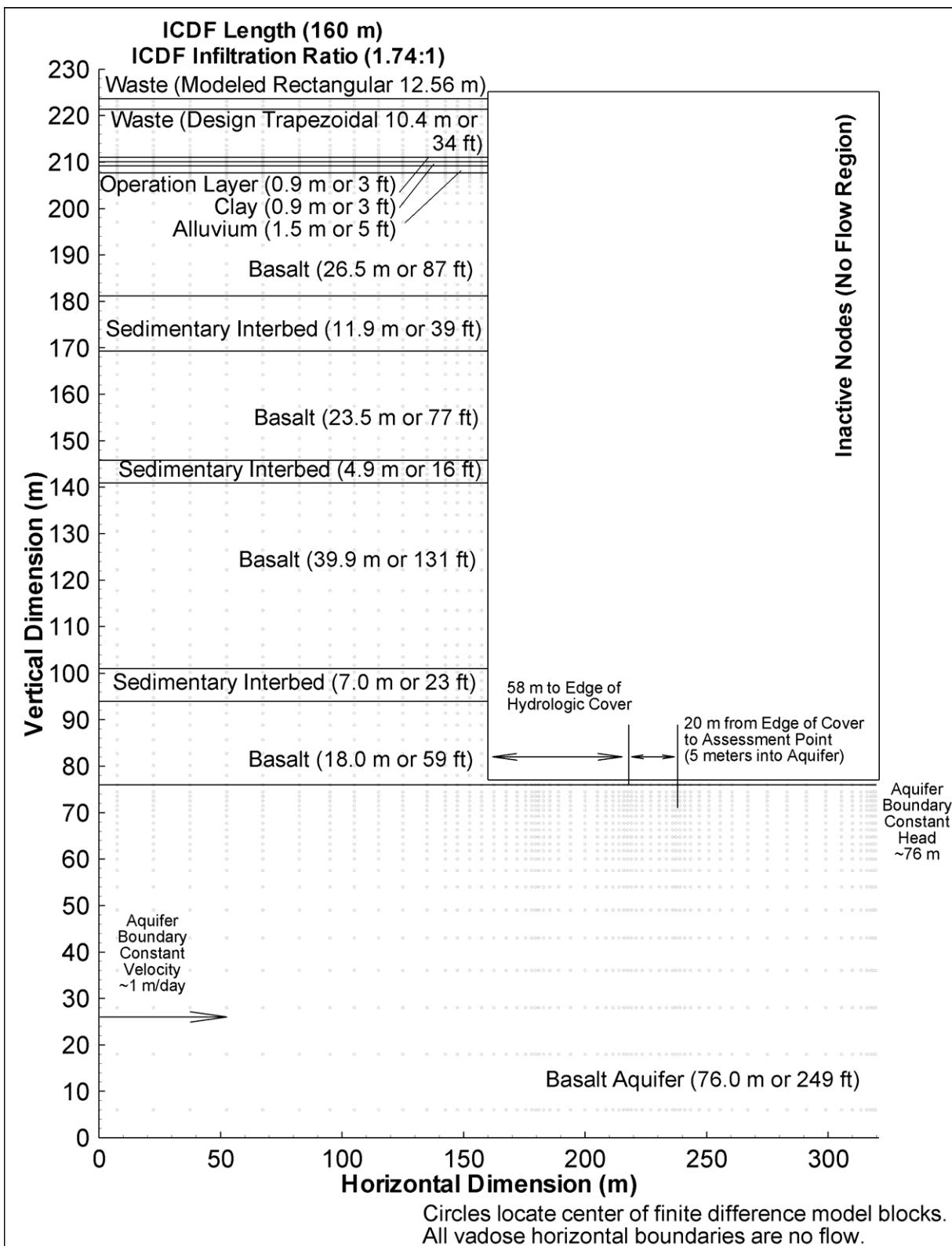


Figure A-1. Conceptual model and finite difference grid used for the ICDF STOMP fate and transport modeling.

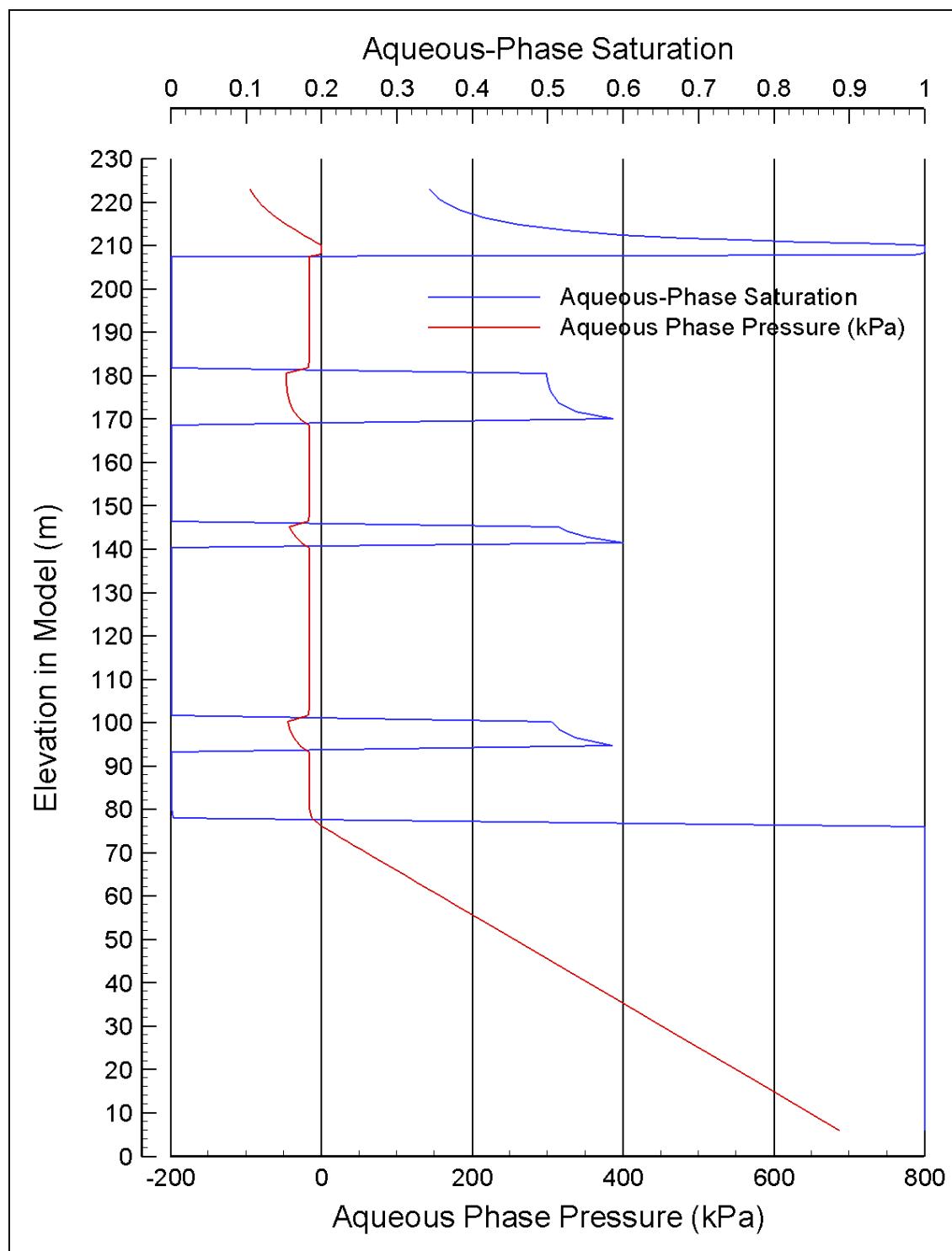


Figure A-2. STOMP steady state saturation and pressure predictions over the ICDF vertical profile.

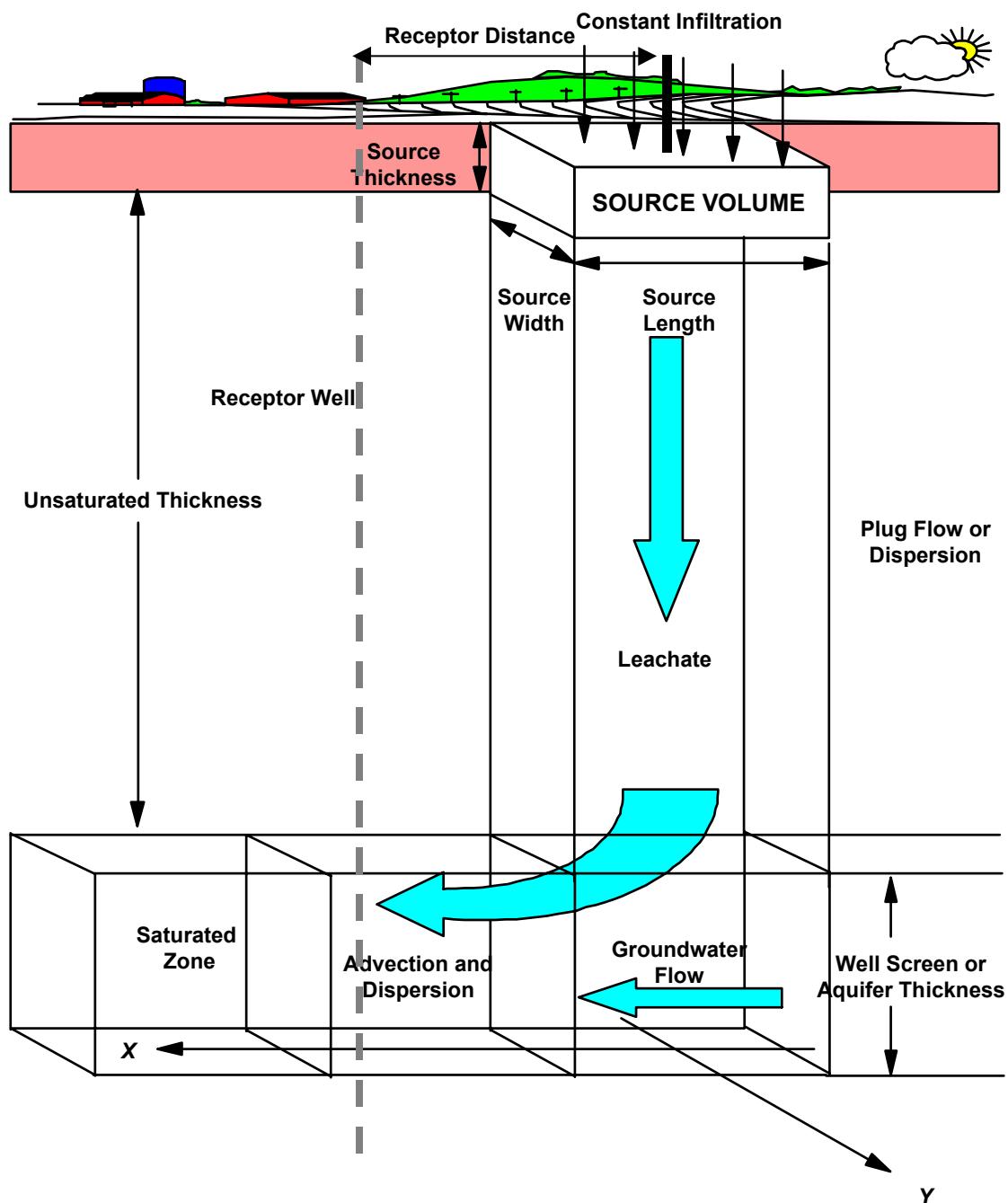


Figure A-3. GWSCREEN conceptual model simulated for the verification runs.

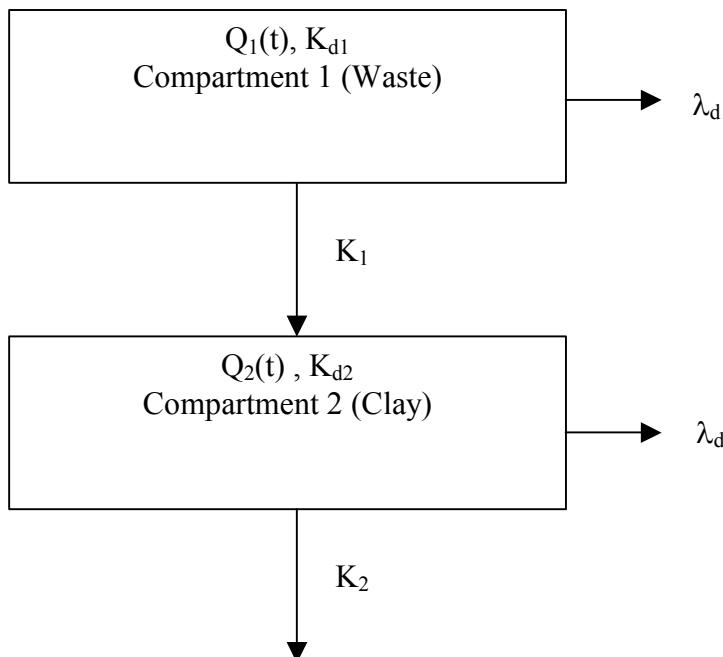


Figure A-4. Schematic of the 2 component source model.

### A.2.1 Two-Compartment Source Term Model

As discussed above, a two-compartment source term model was used to generate a source term for input to GWSCREEN. The advantage of this model over the GWSCREEN built in soil source model is that different Kd values can be used in the waste, the clay, and the interbeds in the unsaturated zone. The basic equations and solution for the two-compartment source term model are presented in this section.

Figure A-4 is a schematic of the conceptual model for a two-compartment source term leaching model. The following system of ordinary equations describes the two-compartment source term leaching model.

The leach rate constants are calculated by solving the following system of ordinary differential equations.

$$\frac{dQ_1}{dt} = -(K_1 + \lambda_d)Q_1 \quad (A-1)$$

$$\frac{dQ_2}{dt} = -(K_2 + \lambda_d)Q_2 \quad (A-2)$$

$$Q_1(t=0) = Q_0 \quad (A-3)$$

$$Q_2(t=0) = 0 \quad (A-4)$$

where,

$$t = \text{time (y)}$$

$Q_1(t)$  = total activity in compartment 1 (Waste) as a function of time (Ci)

$Q_2(t)$  = total activity in compartment 2 (Clay) as a function of time (Ci)

$Q_0$  = initial waste inventory (Ci)

$K_1$  = leach rate constant for layer 1 ( $\text{y}^{-1}$ )

$K_2$  = leach rate constant for layer 2 ( $\text{y}^{-1}$ )

$\lambda_d$  = decay rate constant ( $\text{y}^{-1}$ )

The solution to the system of equations is:

$$F(t) = K_2 Q_2(t) \quad (\text{A-5})$$

$$Q_2(t) = \frac{K_1 Q_0}{(K_2 + \lambda_d) - (K_1 + \lambda_d)} (e^{-(K_1 + \lambda_d)t} - e^{-(K_2 + \lambda_d)t}) \quad (\text{A-6})$$

$$K_1 = \frac{P}{T_1 \left(1 + \frac{K_{d1}\rho_1}{\theta_1}\right) \theta_1} \quad (\text{A-7})$$

$$K_2 = \frac{P}{T_2 \left(1 + \frac{K_{d2}\rho_2}{\theta_2}\right) \theta_2} \quad (\text{A-8})$$

$$\lambda_d = \frac{\ln(2)}{t_{1/2}} \quad (\text{A-9})$$

where,

$F(t)$  = contaminant flux from compartment 2 to the unsaturated zone (Ci/y)

$P$  = infiltration rate (m/y)

$T_1$  = thickness of compartment 1 (m)

$T_2$  = thickness of compartment 2 (m)

$K_{d1}$  = soil to water contaminant distribution coefficient ( $\text{cm}^3/\text{g}$ ) in compartment 1

$K_{d2}$  = soil to water contaminant distribution coefficient ( $\text{cm}^3/\text{g}$ ) in compartment 2

$\theta_1$  = soil moisture content in compartment 1 (unitless)

$\theta_2$  = soil moisture content in compartment 2 (unitless)

$\rho_1$  = soil bulk density in compartment 1 (g/cm<sup>3</sup>)

$\rho_2$  = soil bulk density in compartment 2 (g/cm<sup>3</sup>)

$t_{1/2}$  = radioactive decay half life (y)

This solution was coded in an MS Excel spreadsheet and the contaminant flux [ $F(t)$ ] from the clay layer to the unsaturated zone calculated. The flux was then incorporated into the GWSCREEN input file as a user defined source term.

### **A.3 DESCRIPTION OF THE GWSCREEN VERIFICATION MODEL AND RESULTS**

Parameters were chose for the GWSCREEN simulation to be as close as possible to the parameter values used in the STOMP ICDF design simulation. Table A-1 lists the parameters used in for the two-component source term release model and the GWSCREEN simulation.

Table A-1. GWSCREEN output summarizing the input used for the validation run. (loc3cl1.out)

<b>Site Parameters</b>		
Source Length (m):	1.600E+02	Source Width (m): 1.940E+02
Percolation Rate (m/y):	1.740E-02	
Concentration Vs Time Results for Receptor X = 1.58000E+02 Y = 0.00000E+00		
<b>Source Term and Infiltration Parameters</b>		
Percolation Rate (m/y):	1.740E-02	Initial Inventory (Ci) 9.86E-01
Waste Thickness (m):	1.256E+01	Clay Thickness (m) 0.9
Waste Bulk Density (g/cc):	1.946E+00	Clay Bulk Density (g/cc): 1.586E+00
Waste sorp. coeff.(Kd) cc/g	0.000E+00	Clay sorp. coeff.(Kd)(cc/g) 1.00E+00
Waste Moisture Content:	1.300E-01	Clay Moisture Content: 3.90E-01
<b>Unsaturated Zone Parameters</b>		
Unsat Zone Thickness (m):	2.746E+01	Unsat Bulk Density: 1.360E+00
Unsat Alpha (1/m):	1.066E+00	Unsat n: 1.523E+00
Saturated K in Unsat (m/y):	2.114E+01	Porosity of Unsat Zone: 4.870E-01
Unsat Residual Moisture:	7.200E-02	Unsat Dispersivity (m): 5.000E+00
<b>Aquifer Zone Parameters</b>		
Longitudinal Disp (m):	6.000E+00	Transverse Disp (m): 1.000E-02
Vertical Dispersivity (m):	3.000E+00	

Table A-1. (continued).

Aquifer Thickness (m):	7.600E+01	Well Screen Thickness (m):	5.000E+00	
Darcy Velocity (m/y):	2.190E+01	Aquifer Porosity:	6.000E-02	
Bulk Density (g/cc):	2.491E+00	<b>Calculated Flow Parameters</b>		
Percolation Water Flux (m <sup>3</sup> /y):	5.4010E+02			
Unsaturated Moisture Content:	2.5928E-01			
Unsat Pore Velocity (m/y):	6.7110E-02			
Aquifer Pore Velocity (m/y):	3.6500E+02			
Longitudinal Disp (m**2/y):	2.1900E+03			
Transverse Disp (m**2/y):	3.6500E+00			
Vertical Disp (m**2/y):	1.0950E+03	<b>Contaminant Data</b>		
Contaminant Name:	I129			
Number of Progeny:	0			
Half Life (y):	1.570E+07			
Other Source Loss Rate (1/y):	0.000E+00			
Release File Name:	claykd1.dat			
Kd Unsat (ml/g):	0.000E+00			
Kd Aquifer (ml/g):	0.000E+00			

Results of the GWSCREEN validation simulation are shown in Figure A-5. In general, the shapes of the solutions are similar. However, the peak STOMP predictions are somewhat larger than the GWSCREEN predictions and occur earlier in time. Since the conceptual models are not exactly the same, the difference in results is expected. The difference in results is probably due to a combination of the following. However, no simulations have been performed to test these hypotheses.

1. Slight differences in the moisture content in the waste, clay, and interbeds between the two models. The STOMP model simulates spatially variable moisture content through the vadose zone. The GWSCREEN defines a fixed moisture content over each layer.
2. STOMP's initial soil moisture conditions are based on a 0.01m/y infiltration rate. The transient effects of changes in the moisture content early in the modeling cannot be reproduced with GWSCREEN.

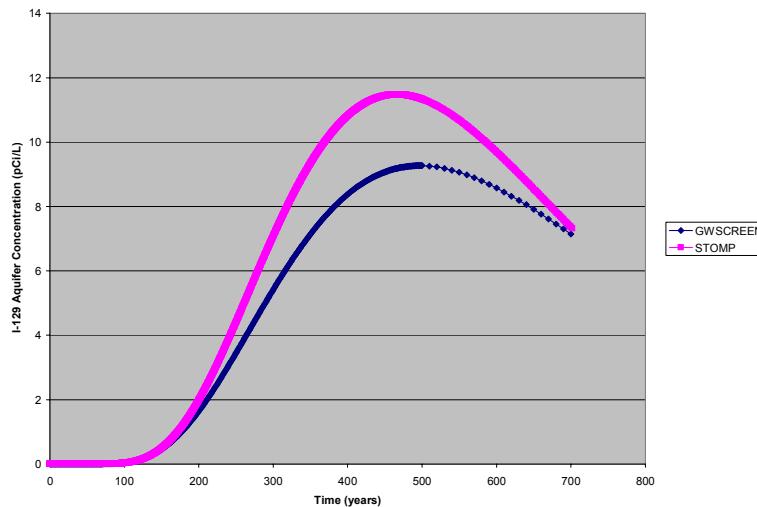


Figure A-5. Comparison of the STOMP ICDF design simulation and GWSCREEN verification results.

#### A.4 References

PNNL, 1996, *Subsurface Transport Over Multiple Phases Description “STOMP” Theory Guide*, PNNL-11217, Pacific Northwest National Laboratory, Richland, Washington.

PNNL, 2000, *Subsurface Transport Over Multiple Phases Description “STOMP” User’s Guide*, PNNL-12034, Pacific Northwest National Laboratory, Richland, Washington,

Rood, A. S., 1999, *GWSCREEN: A Semi-Analytical Model for Assessment of the Groundwater Pathway from Surface or Buried Contamination: Version 2.0 Theory and User’s Manual*, INEEL/EXT-98-00750, Rev. 1, Idaho National Environmental Laboratory, Idaho Falls, Idaho.

## **Appendix B**

### **Evaluation of Design Concentrations as Compared to the Remedial Action Objectives**

431.02  
01/30/2003  
Rev. 11

**ENGINEERING DESIGN FILE**

EDF-ER-275  
Revision 3  
Page 44 of 228

This page intentionally left blank.

## Appendix B

# Evaluation of Design Concentrations as Compared to the Remedial Action Objectives

### B.1 PURPOSE

The purpose of this appendix is to provide an evaluation of the design inventory constituents and concentrations in the “INEEL CERCLA Disposal Facility Design Inventory” Engineering Design File (EDF-ER-264) as compared to the remedial action objectives (RAOs) defined in the OU 3-13 Record of Decision (DOE-ID 1999). This evaluation will provide the basis for consideration of further adjustments, if necessary, in the waste acceptance criteria for the INEEL CERCLA Disposal Facility (ICDF).

### B.2 REQUIREMENTS OR GIVENS

#### B.2.1 Design Inventory

The design inventory constituents and associated site-specific concentrations are published in the “INEEL CERCLA Disposal Facility Design Inventory” (EDF-ER-264). All constituents identified in the Design Inventory will be considered in this evaluation. The design inventory concentrations ( $C_{DI}$ ) provide the starting point for evaluating the RAOs and determining acceptable concentrations.

#### B.2.2 Remedial Action Objective

The RAO provides the basis for calculating the required concentration based criteria. The RAO specific to the ICDF is stated in the OU 3-13 Record of Decision (ROD) (DOE-ID 1999, page 8-2) as:

*“Maintain caps placed over contaminated soil or debris areas that are contained in place and the closed ICDF-complex, to prevent the release of leachate to underlying groundwater which would result in exceeding a cumulative carcinogenic risk of 1E-4, a total HI of 1; or applicable State of Idaho groundwater quality standards (i.e., MCLs) in the SRPA.”*

This RAO provides the basis for developing three criteria:

- Cumulative excess lifetime carcinogenic risk (ELCR) in groundwater of 1E-4
- Total non-carcinogenic hazard index (HI) in groundwater of 1
- Achieving the maximum contaminant levels (MCLs) in groundwater (e.g., individual constituents, total alpha of 15 pCi/L).

#### B.2.3 Background Concentrations

Idaho National Engineering and Environmental Laboratory (INEEL) background constituents and concentrations are evaluated and presented in *Background Dose Equivalent Rates and Surficial Soil Metal and Radionuclide Concentrations for the Idaho National Engineering Laboratory* (INEEL 1994). For the

purposes of these calculations, the 95%/95% Upper Tolerance Limits are used as presented in Tables 22 and 24. This is consistent with the background values referenced in the ROD (DOE/ID 1999).

## **B.2.4 Constituent Half Life**

The constituents radiological or environmental half life in years is referenced as follows. The radionuclide half-lives were gathered from:

- CRC Handbook of Chemistry and Physics (CRC 1995)
- EPA's "Radionuclide Carcinogenicity Slope Factors," Health Effects Assessment Summary Tables (HEAST) - Radionuclides Table (EPA 2001a).

The non-radiological half lives were gathered from a number of websites and other references:

- ChemFinder.com 2001
- Spectrum Laboratories, Inc., 2001
- International Program on Chemical Safety INCHEM, Behavior and Determination of Volatile Organic Chemicals in Soil, A Literature Review (EPA 1993)
- ARS Pesticide Properties Database 2001
- The Handbook of Environmental Degradation Rates (Howard et al. 1991).
- Handbook of Environmental Data on Organic Chemicals (Verschueren 2001).

## **B.3 Methodology and Implementation**

### **B.3.1 Evaluate Background Concentrations**

The design inventory concentrations ( $C_{DI}$ ) are compared with background concentrations. Those constituents that have a concentration less than background are eliminated from the risk evaluations (i.e., carcinogenic and non-carcinogenic evaluations). There are 15 constituents eliminated from the risk evaluations based on this comparison. They are shown in Table B-1. These 15 constituents will not be evaluated with respect to the carcinogenic or non-carcinogenic risks. These constituents will remain in the MCL evaluation.

Table B-1. Constituents with  $C_{DI} <$  Background.

Ra228	Calcium	Nickel
Aluminum	Cobalt	Potassium
Arsenic	Iron	Sodium
Barium	Magnesium	Thallium
Beryllium	Manganese	Vanadium

## B.3.2 Determine Constituent Groundwater Concentrations

The concentration ( $C_T$ ) versus time (T) is calculated for all design inventory constituents. The constituent concentration ( $C_T$ ) in groundwater for each time step at time "T" is calculated based on equations (B-1) and (B-2). A summary of the input parameters is provided in Table B-2 at the end of this appendix.

$$C_T = [(C_{DI}) (DAF_T/1000) (e^{-\gamma T})] \quad (B-1)$$

where

$C_T$	Concentration at time "T" (units - pCi/L or mg/L)
$C_{DI}$	Concentration at original design inventory provided in EDF-ER-264 Note: convert Ci/kg to pCi/kg for radionuclides (units - pCi/kg or mg/kg)
$DAF_T$	Dilution / Attenuation Factor at time "T" as modeled in the fate and transport studies (EDF-ER-275). The surrogate dilution/attenuation factor (DAF) is selected based on the constituents weighted average vadose zone $K_d$ . Note: equation includes conversion to kg/L (units - kg/m <sup>3</sup> )
$e^{-\gamma T}$	Decay Factor, where: (Note: 1 is entered if the constituent does not decay) (unitless)
$e$	2.718
$\gamma$	Lamda, see equation (B-2) (units – years)
T	Time provided in the fate and transport modeling results (units – years)

$$\gamma = \ln 2 / t \quad (B-2)$$

where

$\ln 2$	0.6931
t	Constituent half life (units – years)

### B.3.2.1 Weighted Average $K_d$ s

The weighted average  $K_d$  is selected as an indicator of the relative mobility of specific contaminants in the vadose zone within and beneath the ICDF. The value is computed by summing the results of multiplying the fractional vadose zone thickness of each stratigraphic unit by the contaminant-specific  $K_d$  for each unit. The weighted average  $K_d$  is used to group constituents with similar anticipated travel times through the vadose zone.

$$K_d \text{ weighted average} = \Sigma( K_d * \text{fractional thickness})_{\text{stratigraphic unit}} \quad (B-3)$$

where

$K_d$  Distribution coefficient representing the tendency for a substance to adsorb to soil. The greater the  $K_d$  value, the greater the extent of adsorption in soil. The  $K_d$ s for non-organics are provided in a letter from Talley Jenkins<sup>c</sup> (Units – mL/g)

Fractional Thickness Thickness of each unit divided by the total cross-section (EDF-ER-275), where:  
(unitless)

Stratigraphic Unit	Thickness (m)	Fraction
Waste soils	12.56	0.085
Operations layer	0.9	0.006
Clean alluvium	1.52	0.010
Clay materials	0.9	0.006
Interbed materials	23.8	0.161
Vadose zone basalt	107.9	0.731
Total Thickness	147.58	

The  $K_d$  for organic constituents is determined through the use of equation (B-4). This  $K_d$  is substituted into equation (B-3) in support of the weighted average  $K_d$  calculation.

$$K_d = K_{oc} * \text{Organic Carbon Fraction} \quad (\text{B-4})$$

where

$K_{oc}$  Organic Carbon partitioning coefficient (La Grega, et al, 1994, EPA 2000; ORNL 2001)  
(Units – mL/g)

Organic Carbon Fraction The fraction of organic carbon in each stratigraphic unit (Colwell 1988), where:  
(unitless)

Stratigraphic Unit	Fractional Thickness
Waste soils	0.0025
Operations layer	0.0025
Clean alluvium	0.0025
Clay materials	0
Interbed materials	0.0005
Vadose zone basalt	0

---

c. Jenkins, T., DOE, letter to Martin Doornbos, BBWI, July 3, 2001,  $K_d$  values for INTEC groundwater modeling (EM-ER-01-115).

### B.3.2.2 Dilution/Attenuation Factors

The dilution/attenuation factor (DAF) is determined based on the Subsurface Transport Over Multiple Phases (STOMP) Model discussed and presented in EDF-ER-275. The STOMP Model utilized eight surrogate constituent  $K_d$ s that are representative of the  $K_d$  range of all design inventory constituents. The model output provided in support of this process includes the DAF. The application of the various DAFs is based on the weighted average  $K_d$ .

where

DAF	Dilution / Attenuation Factor, modeled in the fate and transport studies (EDF-ER-275) The surrogate application to a specific constituent is identified below. (Units - kg/L)	
	If weighted average $K_d < 0.006$ , or if $K_d$ not listed	Then use surrogate 1
	If weighted average $0.006 \leq K_d < 0.058$	Then use surrogate 2
	If weighted average $0.058 \leq K_d < 1.950$	Then use surrogate 3
	If weighted average $1.950 \leq K_d < 2.426$	Then use surrogate 4
	If weighted average $2.426 \leq K_d < 4.464$	Then use surrogate 5
	If weighted average $4.464 \leq K_d < 18.592$	Then use surrogate 6
	If weighted average $18.592 \leq K_d < 91.120$	Then use surrogate 7
	If weighted average $K_d \geq 91.120$	Then use surrogate 8

### B.3.3 Constituent Concentration Over Time

The above calculations are utilized to determine the individual constituent concentrations over time. The maximum concentration of each constituent over the period of evaluation is provided in Table B-3 at the end of this appendix.

### B.3.4 Compare $C_T$ to the Remedial Action Objectives

The three key components to the RAOs include cumulative excess lifetime carcinogenic risk, cumulative hazard index, and MCLs. The input parameters to support the comparison of the design inventory to the RAOs is provided in Table B-4 at the end of this appendix.

#### B.3.4.1 Cumulative Excess Lifetime Carcinogenic Risk

A RAO Risk ( $R_{RISK@T}$ ) versus time (T) is calculated for each individual design inventory constituent that potentially poses a carcinogenic risk. Note that those constituents with a  $C_{DI}$  less than background are not included in this evaluation. The  $R_{RISK}$  in groundwater at time (T) is calculated based on equation (B-5).

$$R_{RISK@T} = C_T / \text{Risk Factor} \quad (\text{B-5})$$

where

$R_{RISK@T}$	Carcinogenic risk of an individual constituent at time "T" (unitless)
$C_T$	Concentration at time "T" as calculated by equation (B-1) (units – pCi/L or mg/L)
Risk Factor	The risk per unit concentration as defined by equation (B-6) (units – pCi/L or mg/L)

The Risk Factor is calculated based on equation (B-6):

$$\text{Risk Factor} = RBC / TR \quad (\text{B-6})$$

where

Risk Factor	The risk associated with 1 unit concentration (units – pCi/L or mg/L)
RBC	Individual carcinogenic risk-based concentrations (RBC) representing an ELCR of $1 \times 10^{-4}$ as defined in Appendix C. (units – pCi/L or mg/L )
TR	Target risk defined as $1 \times 10^{-4}$ (unitless)

The cumulative RAO Risk ( $R_{\Sigma RISK}$ ) versus time (T) curve representing the sum of each  $R_{RISK@T}$  for each individual design inventory constituent representing a carcinogenic risk using the design recharge rate of 0.0001 m/year. The  $R_{\Sigma RISK}$  in groundwater for each time (T) is calculated based on equation (B-7). The curve is prepared by graphing the  $R_{\Sigma RISK}$  versus T as shown in Figure B-1. The figure includes a line indicating the acceptable cumulative carcinogenic risk value of 1E-4. As indicated on this figure, the  $C_T$  values are protective based on this RAO.

$$R_{\Sigma RISK} = \sum R_{RISK@T} \quad (\text{B-7})$$

#### B.3.4.2 Hazard Index

A RAO HI ( $R_{HI@T}$ ) versus time (T) is calculated for each individual design inventory constituent that potentially poses a non-carcinogenic health effect. Note that those constituents with a  $C_{DI}$  less than background are not included in this evaluation. The  $R_{HI}$  in groundwater for each time (T) is calculated based on equation (B-8).

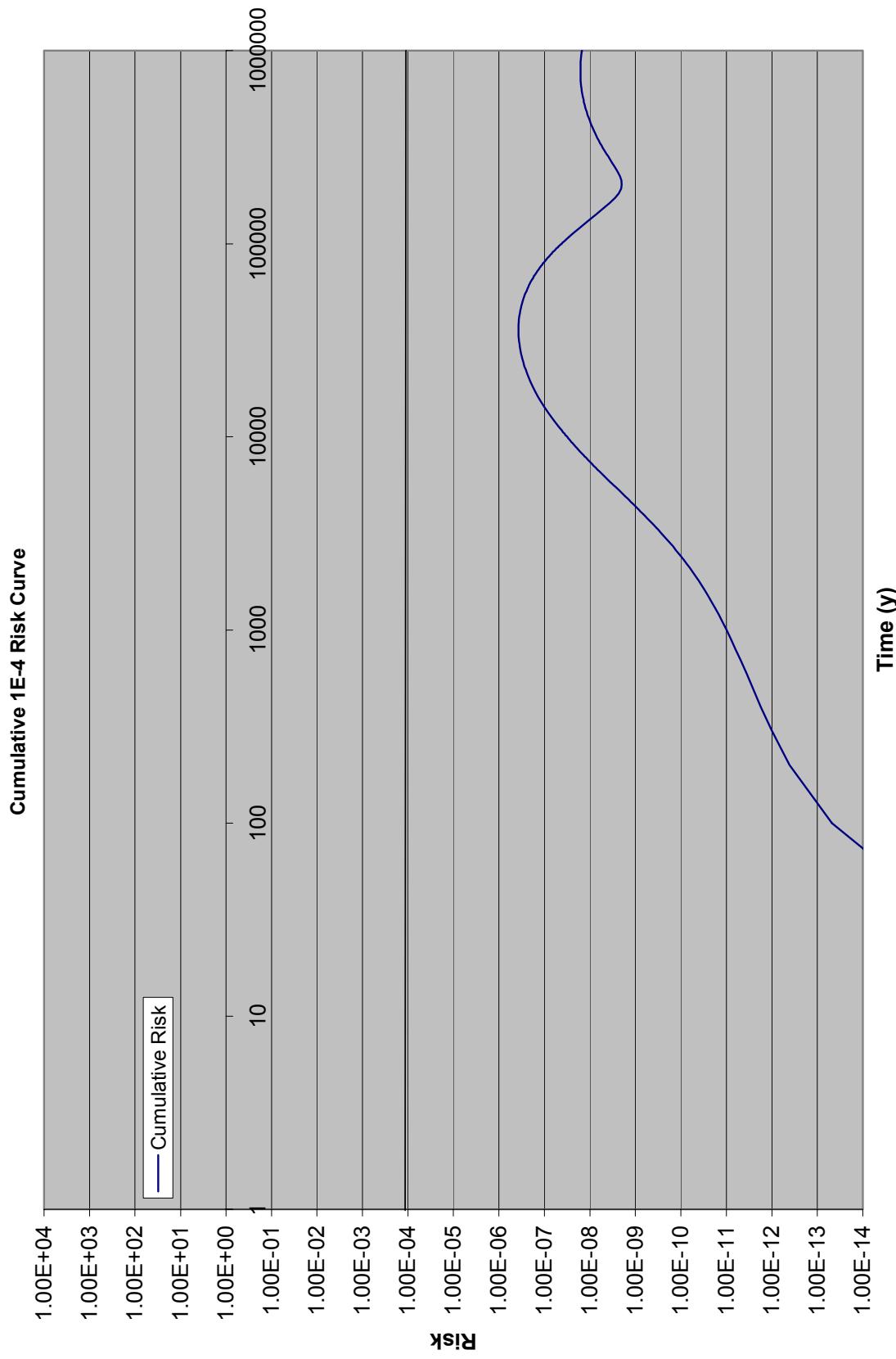


Figure B-1. Cumulative excess lifetime carcinogenic risk over time.

$$R_{HI@T} = C_T / \text{Risk Factor}$$

(B-8)

where

$R_{HI@T}$	Non-carcinogenic HI of an individual constituent at time "T" (unitless)
$C_T$	Concentration at time "T" as calculated by equation (B-1) (units - pCi/L or mg/L)
Risk Factor	The risk associated with 1 unit concentration as defined by equation (B-9) (units – pCi/L or mg/L)

The Risk Factor is calculated based on the following equation:

$$\text{Risk Factor} = RBC / THI$$

(B-9)

where

Risk Factor	The risk associated with 1 unit concentration (units – pCi/L or mg/L)
RBC	Individual non-carcinogenic RBC representing a HI of 1 as defined in Appendix C. (units – pCi/L or mg/L )
THI	Target HI defined as 1 (unitless)

The cumulative RAO Hazard Index ( $R_{\Sigma HI}$ ) versus time (T) curve representing the sum of each individual design inventory constituent representing a non-carcinogenic risk using the design recharge rate of 0.0001 m/year. The  $R_{\Sigma HI}$  in groundwater for each time (T) is calculated based on equation (B-10). The curve is prepared by graphing the  $R_{\Sigma HI}$  versus T as shown in Figure B-2. The graph includes a line indicating the acceptable cumulative non-carcinogenic hazard index of 1. As indicated on this figure, the  $C_T$  values are protective based on this RAO.

$$R_{\Sigma HI} = \sum R_{HI@T}$$
 (B-10)

### B.3.4.3 Individual and Cumulative MCLs

The MCL RAO addresses four key elements for evaluation; individual constituents, total alpha particles, beta particles and photon emitters, and Ra-226 and Ra-228 combined.

1. Individual Constituents. The MCL limit for each constituent is based on U.S. Environmental Protection Agency's (EPA's) website at [www.epa.gov/safewater/mcl.html](http://www.epa.gov/safewater/mcl.html) (EPA 2001b). These limits are compared to the  $C_T$  maximum values over the evaluation period. Table B-5 provides both values for comparative purposes at the end of this appendix. As indicated by this table, the  $C_T$  values are protective based on this RAO element.

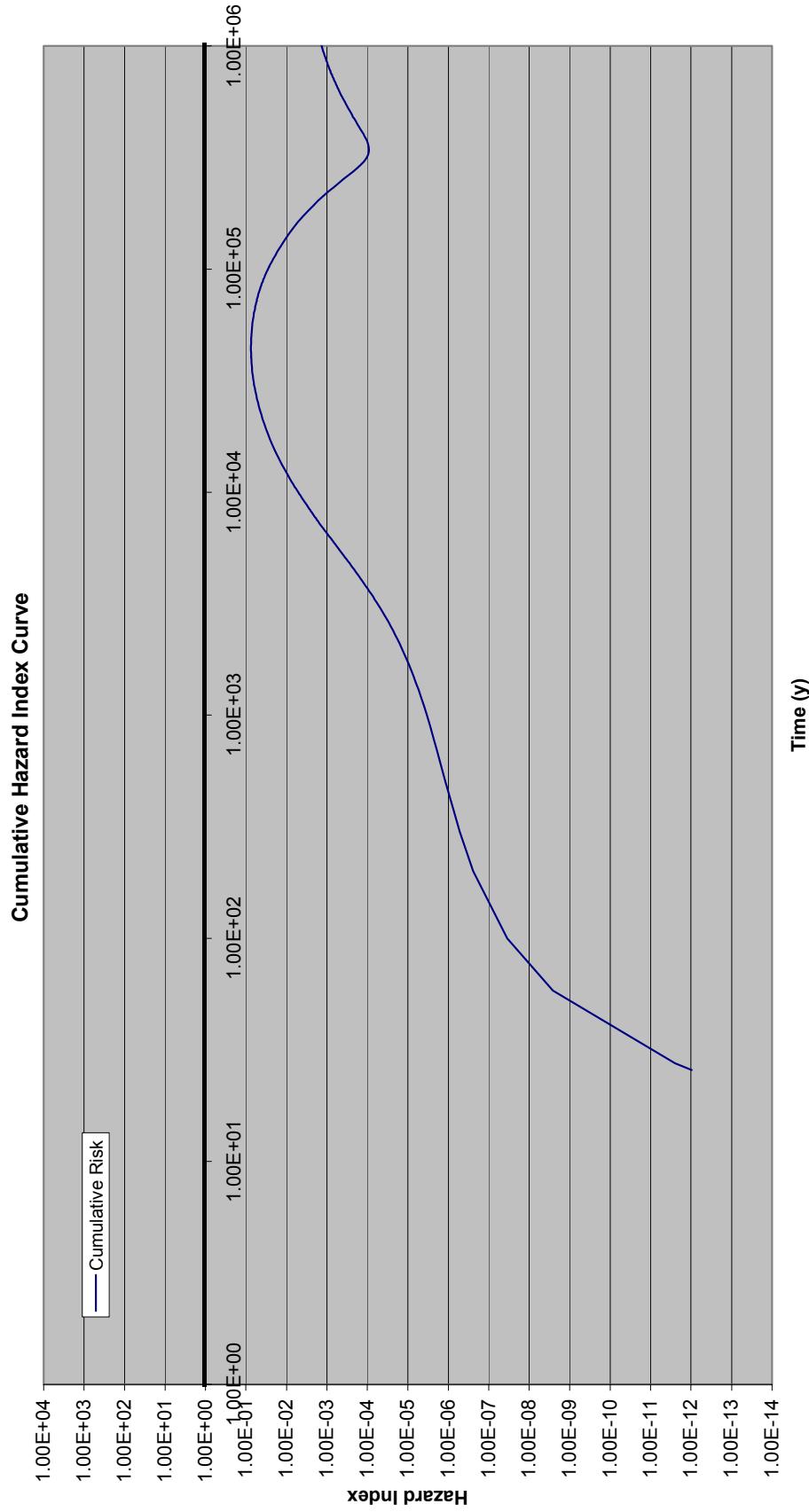


Figure B-2. Cumulative hazard index over time.

2. Total Alpha Particles not to exceed 15 pCi/L. Alpha particle emitters have a cumulative MCL of 15 pCi/L. All alpha emitters were identified and concentrations were accumulated to evaluate the cumulative value as shown in Figure B-3. As indicated on this figure, the  $C_T$  values are protective based on this RAO element. The 15 pCi/L limit could not be shown on the graph because of the scale.
3. Beta particles and photon emitters not to exceed 4 mrem/year. Beta particles and photon emitters have a cumulative MCL of 4 mrem/yr total dose to an organ, factoring in potential total body accumulation. Per EPA guidance (EPA 1991), this calculation is based on the equation (B-11). All beta particles and photon emitters were identified and calculations were made to evaluate the cumulative values as shown on Figure B-4. As indicated on this figure, the  $C_T$  values are protective based on this RAO element. The 4 mrem/year could not be shown on the graph because of the scale.

$$\text{Dose}_{\text{Organ } X} = (C_{T}^A / C_4^A) + (C_{T}^B / C_4^B) + \dots + (C_{T}^N / C_4^N) \times 4 \text{ mrem/year} \quad (\text{B-11})$$

where

$\text{Dose}_{\text{Organ } X}$  Dose specific to the organ (note that the total body dose must be included to ensure accurate cumulative affects.)  
(units = mrem/year)

$C_{T}^A$  Concentration of the specific isotope “A” at a time “T”  
(units = pCi/L)

$C_4^A$  The 4 mrem/year dose equivalent concentration for organ “X” of isotope “A” at time “T.” Values are provided in EPA guidance (EPA 1976).  
(units = pCi/L)

4. Combined Ra-226 and Ra-228 not to exceed 5 pCi/L. The fourth and final element of the MCL elements is the cumulative MCL for Ra-226 and Ra-228 of 5 pCi/L. Based on the maximum values presented in Table B-3, the cumulative value of these two isotopes is well under the 5 pCi/L range. As such, the  $C_T$  values are protective based on this RAO elements.

## B. 4 CONCLUSIONS

The RAOs are achieved based on the design inventory concentrations as modeled in groundwater. Based on this evaluation, it is anticipated that the constituent concentration inventory for acceptance at the ICDF will be increased beyond that of the original design inventory concentrations.

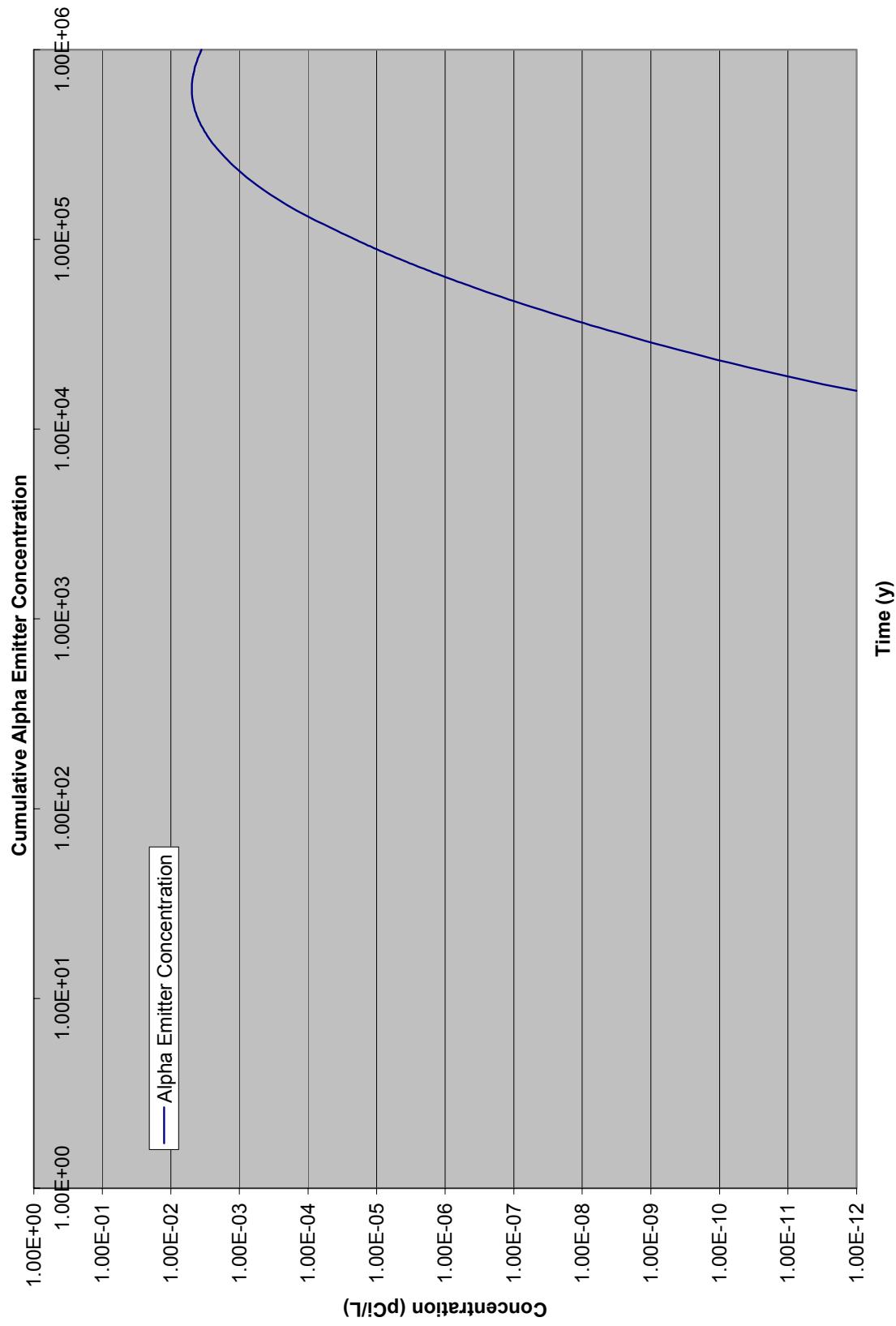


Figure B-3. Cumulative total alpha summary over time.

### MCL Curves

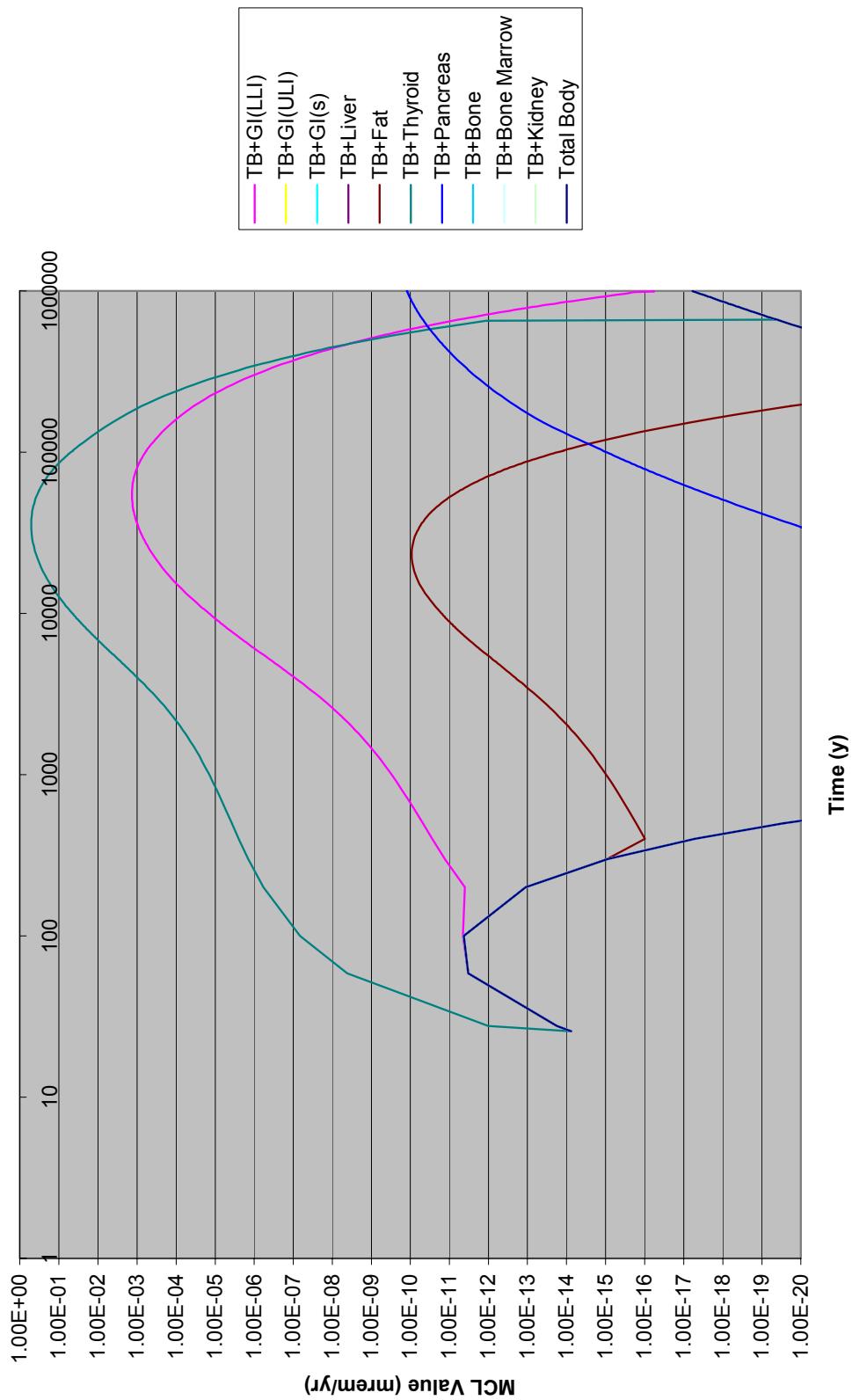


Figure B-4. Total beta particle and photon emitter dose summary over time.

## B.5 REFERENCES

ARS Pesticide Properties Database, 2001, <http://wizard.arsusda.gov/acsl/textfiles>, website visited November 2001.

ChemFinder.com, 2001, <http://chemfinder.cambridgeSoft.com>, website visited November 2001.

Colwell, F.S., 1988, *Final Report: Microbial Examination of RWMC Surface And Subsurface Soils and Biodegradation of Low Molecular Weight Hydrocarbons Using Microorganisms Indigenous to RWMC*, ST-BEG-03-88, EG&G Idaho, Inc.

CRC, 1995, *Handbook of Chemistry and Physics*, 82nd edition, CRC Press, Boca Raton, Florida.

DOE-ID, 1999, *Final Record of Decision, Idaho Nuclear Technology and Engineering Center, Operable Unit 3-13*, DOE/ID-10660, Department of Energy Idaho Operations Office, Idaho Falls, Idaho, U.S. Environmental Protection Agency Region 10, and State of Idaho Department of Health and Welfare.

EDF-ER-264, 2001, "INEEL CERCLA Disposal Facility Design Inventory," Draft A, Environmental Restoration Program, Idaho National Engineering and Environmental Laboratory, March 2001.

EDF-ER-275, 2001, "Fate and Transport Modeling Results," Draft A, Environmental Restoration Program, Idaho National Engineering and Environmental Laboratory, October 2001.

EPA 1976, *National Interim Primary Drinking Water Regulations*, EPA-570/9-76-003, Office of Water Supply, Environmental Protection Agency.

EPA, 1991, *Risk Assessment Guidance for Superfund: Volume 1 – Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals)*, EPA/540/R-92/003, Environmental Protection Agency.

EPA, 1993, "International Program on Chemical Safety INCHEM, Behavior and Determination of Volatile Organic Chemicals in Soil," *A Literature Review*, U.S. Environmental Protection Agency.

EPA, 2000, Region IX Preliminary Remediation Goal Chemical-Physical Data Table, <http://www.epa.gov/docs/region09/waste/sfund/prg/index.html>, website visited November 2001.

EPA, 2001a, "Radionuclide Carcinogenicity Slope Factors," Health Effects Assessment Summary Tables (HEAST) - Radionuclides Table <http://www.epa.gov/radiation/heast>, website visited November 2001.

EPA 2001b, <http://www.epa.gov/safewater/regs.html>, website visited September 2001.

Howard, P. H., R. S. Boethling, W.F. Jarris, W. Meylam , 1991, *The Handbook of Environmental Degradation Rates*. Bocha Raton, CRC Press.

INEEL, 1994, *Background Dose Equivalent Rates and Surficial Soil Metal and Radionuclide Concentrations for the Idaho National Engineering Laboratory*, INEL-94/0250, Idaho National Environmental and Engineering Laboratory.

La Grega, M.D., Buckingham, P. L, Evans, J. C., 1994, *Hazardous Waste Management*, McGraw-Hill, Inc., New York

ORNL, 2001, Risk Assessment Information System, Chemical-Specific Factors (Koc) Oak Ridge National Laboratory, <http://risk.lsd.ornl.gov>, website visited September 2001.

Spectrum Laboratories, Inc., 2001, <http://www.speclab.com/elements>, website visited November 2001.

Verschueren K, 2001, Handbook of Environmental Data on Organic Chemicals, 4<sup>th</sup> edition, Wiley-Interscience, John Wiley & Sons, Inc. Scientific, Technical, and Medical Division, 605 Third Avenue, New York, New York.

Table B-2. Summary of input parameters for concentration calculations.

Constituent	Organic Carbon			Vadose Zone			Surrogates
	Design Inventory (C <sub>di</sub> ) (pCi/kg or mg/kg)	Partition Coefficient (K <sub>oc</sub> ) (mL/g)	Soils K <sub>d</sub> (mL/g)	Waste Soils K <sub>d</sub> (mL/g)	Operations Layer K <sub>d</sub> (mL/g)	Clean Alluvium K <sub>d</sub> (mL/g)	
Ac225	5.12E-05	NA	4.5E+02	4.5E+02	2.4E+03	4.5E+02	0.0E+00
Ac227	2.04E-02	NA	4.5E+02	4.5E+02	2.4E+03	4.5E+02	0.0E+00
Ac228	1.52E-07	NA	4.5E+02	4.5E+02	2.4E+03	4.5E+02	0.0E+00
Ag106	0.00E+00	NA	9.0E+01	9.0E+01	1.8E+02	9.0E+01	2.5E+01
Ag108	3.69E-06	NA	9.0E+01	9.0E+01	1.8E+02	9.0E+01	0.0E+00
Ag108m	8.00E+02	NA	9.0E+01	9.0E+01	1.8E+02	9.0E+01	0.0E+00
Ag109m	4.92E-09	NA	9.0E+01	9.0E+01	1.8E+02	9.0E+01	0.0E+00
Ag110	5.18E-08	NA	9.0E+01	9.0E+01	1.8E+02	9.0E+01	0.0E+00
Ag110m	5.55E-06	NA	9.0E+01	9.0E+01	1.8E+02	9.0E+01	0.0E+00
Ag111	0.00E+00	NA	9.0E+01	9.0E+01	1.8E+02	9.0E+01	0.0E+00
Am241	2.38E+04	NA	3.4E+02	3.4E+02	3.4E+02	3.4E+02	0.0E+00
Am242	4.53E-02	NA	3.4E+02	3.4E+02	3.4E+02	3.4E+02	0.0E+00
Am242m	4.52E-02	NA	3.4E+02	3.4E+02	3.4E+02	3.4E+02	0.0E+00
Am243	3.34E-01	NA	3.4E+02	3.4E+02	3.4E+02	3.4E+02	0.0E+00
Am245	0.00E+00	NA	3.4E+02	3.4E+02	3.4E+02	3.4E+02	0.0E+00
Am246	1.38E-22	NA	3.4E+02	3.4E+02	3.4E+02	3.4E+02	0.0E+00
At217	5.12E-05	NA	0.0E+00	0.0E+00	1.0E+00	0.0E+00	6.0E-03
Ba136m	0.00E+00	NA	5.0E+01	5.0E+01	5.0E+01	5.0E+01	0.0E+00
Ba137m	2.31E+07	NA	5.0E+01	5.0E+01	5.0E+01	5.0E+01	0.0E+00
Ba140	0.00E+00	NA	5.0E+01	5.0E+01	5.0E+01	5.0E+01	0.0E+00
Be10	1.14E-03	NA	2.5E+02	2.5E+02	1.3E+03	2.5E+02	0.0E+00
Bi210	1.09E-03	NA	1.0E+02	1.0E+02	1.0E+02	1.0E+02	0.0E+00
Bi211	1.83E-02	NA	1.0E+02	1.0E+02	1.0E+02	1.0E+02	0.0E+00
Bi212	5.53E-01	NA	1.0E+02	1.0E+02	1.0E+02	1.0E+02	0.0E+00
Bi213	0.00E+00	NA	1.0E+02	1.0E+02	1.0E+02	1.0E+02	0.0E+00
Bi214	5.62E-03	NA	1.0E+02	1.0E+02	1.0E+02	1.0E+02	0.0E+00
Bk249	2.16E-18	NA	4.0E+03	4.0E+03	4.0E+03	4.0E+03	0.0E+00
Bk250	7.75E-23	NA	4.0E+03	4.0E+03	4.0E+03	4.0E+03	0.0E+00
C14	4.61E-02	NA	5.0E+00	5.0E+00	1.0E+02	5.0E+00	0.0E+00
Cd109	4.92E-09	NA	6.0E+00	6.0E+00	6.0E+00	6.0E+00	0.0E+00
Cd113m	1.62E+03	NA	6.0E+00	6.0E+00	6.0E+00	6.0E+00	0.0E+00
Cel44	4.25E-51	NA	6.0E+00	6.0E+00	6.0E+00	5.6E+02	0.0E+00
Cel41	1.80E-68	NA	5.0E+02	5.0E+02	5.0E+02	5.1E+02	2.0E+04
Cel42	0.00E+00	NA	5.0E+02	5.0E+02	5.0E+02	5.1E+02	2.0E+04
Cel44	1.81E+00	NA	5.0E+02	5.0E+02	5.0E+02	5.1E+02	2.0E+04
Cf249	4.12E-13	NA	5.1E+02	5.1E+02	5.1E+02	5.1E+02	2.0E+04
Cf250	2.11E-13	NA	5.1E+02	5.1E+02	5.1E+02	5.1E+02	2.0E+04
Cf251	9.52E-16	NA	5.1E+02	5.1E+02	5.1E+02	5.1E+02	2.0E+04
Cf252	2.24E-17	NA	5.1E+02	5.1E+02	5.1E+02	5.1E+02	2.0E+04
Cm241	1.30E-77	NA	4.0E+03	4.0E+03	4.0E+03	4.0E+03	0.0E+00
Cm242	5.39E-14	NA	4.0E+03	4.0E+03	4.0E+03	4.0E+03	0.0E+00

Table B-2. (continued)

Constituent	Organic Carbon			Operations Layer K <sub>d</sub> (mL/g)			Clean Alluvium K <sub>d</sub> (mL/g)			Clay Materials K <sub>d</sub> (mL/g)			Interbeds Materials K <sub>d</sub> (mL/g)			Vadose Zone Basalt K <sub>d</sub> (mL/g)			Vadose Zone Weighted Average K <sub>d</sub> (mL/g)			Vadose Zone Half-Life (yr)		
	Design Inventory (C <sub>Dl</sub> ) (pCi/kg or mg/kg)	Partition Coefficient (K <sub>oc</sub> ) (mL/g)	Waste Soils K <sub>d</sub> (mL/g)	Operations Layer K <sub>d</sub> (mL/g)	Clean Alluvium K <sub>d</sub> (mL/g)	Clay Materials K <sub>d</sub> (mL/g)	Interbeds Materials K <sub>d</sub> (mL/g)	Vadose Zone Basalt K <sub>d</sub> (mL/g)	Average K <sub>d</sub> (mL/g)	Vadose Zone Weighted Average K <sub>d</sub> (mL/g)	Vadose Zone Half-Life (yr)	Surrogates												
Cm243	3.55E-03	NA	4.0E+03	4.0E+03	4.0E+03	6.0E+03	4.0E+03	4.0E+00	1.1E+03	2.9E+01	8													
Cm244	1.80E+00	NA	4.0E+03	4.0E+03	4.0E+03	6.0E+03	4.0E+03	4.0E+00	1.1E+03	1.8E+01	8													
Cm245	8.02E-05	NA	4.0E+03	4.0E+03	4.0E+03	6.0E+03	4.0E+03	4.0E+00	1.1E+03	8.5E+03	8													
Cm246	1.79E-06	NA	4.0E+03	4.0E+03	4.0E+03	6.0E+03	4.0E+03	4.0E+00	1.1E+03	4.7E+03	8													
Cm247	6.39E-13	NA	4.0E+03	4.0E+03	4.0E+03	6.0E+03	4.0E+03	4.0E+00	1.1E+03	1.6E+07	8													
Cm248	1.95E-13	NA	4.0E+03	4.0E+03	4.0E+03	6.0E+03	4.0E+03	4.0E+00	1.1E+03	3.4E+05	8													
Cm250	5.53E-22	NA	4.0E+03	4.0E+03	4.0E+03	6.0E+03	4.0E+03	4.0E+00	1.1E+03	9.7E+03	8													
Co-57	3.69E+00	NA	1.0E+01	1.0E+01	1.0E+01	1.0E+01	1.0E+01	1.0E+00	1.0E+01	7.4E+01	6													
Co-58	5.88E-14	NA	1.0E+01	1.0E+01	1.0E+01	1.0E+01	1.0E+01	1.0E+00	1.0E+01	1.9E+01	6													
Co-60	1.93E+05	NA	1.0E+01	1.0E+01	1.0E+01	1.0E+01	1.0E+01	1.0E+00	1.0E+01	5.3E+00	6													
Cr-51	2.30E-51	NA	3.0E+01	3.0E+01	3.0E+01	3.0E+01	3.0E+01	3.0E+00	1.7E+01	7.6E+02	6													
Cs132	0.00E+00	NA	5.0E+02	5.0E+02	5.0E+02	5.0E+02	5.0E+02	5.0E+00	1.4E+02	1.8E+02	8													
Cs134	1.12E+04	NA	5.0E+02	5.0E+02	5.0E+02	5.0E+02	5.0E+02	5.0E+00	1.4E+02	2.1E+00	8													
Cs135	3.58E+01	NA	5.0E+02	5.0E+02	5.0E+02	5.0E+02	5.0E+02	5.0E+00	1.4E+02	2.3E+06	8													
Cs136	0.00E+00	NA	5.0E+02	5.0E+02	5.0E+02	5.0E+02	5.0E+02	5.0E+00	1.4E+02	3.6E+02	8													
Cs137	2.44E+07	NA	5.0E+02	5.0E+02	5.0E+02	5.0E+02	5.0E+02	5.0E+00	1.4E+02	3.0E+01	8													
Er169	0.00E+00	NA	2.4E+02	2.4E+02	2.4E+02	2.4E+02	2.4E+02	2.4E+00	6.4E+01	2.5E+02	7													
Eu150	1.73E-05	NA	3.4E+02	3.4E+02	3.4E+02	3.4E+02	3.4E+02	3.4E+00	9.1E+01	1.4E+03	8													
Eu152	9.68E+05	NA	3.4E+02	3.4E+02	3.4E+02	3.4E+02	3.4E+02	3.4E+00	9.1E+01	1.3E+01	8													
Eu154	8.21E+05	NA	3.4E+02	3.4E+02	3.4E+02	3.4E+02	3.4E+02	3.4E+00	9.1E+01	8.8E+00	8													
Eu155	1.76E+05	NA	3.4E+02	3.4E+02	3.4E+02	3.4E+02	3.4E+02	3.4E+00	9.1E+01	5.0E+00	8													
Eu156	0.00E+00	NA	3.4E+02	3.4E+02	3.4E+02	3.4E+02	3.4E+02	3.4E+00	9.1E+01	4.2E+02	8													
Fe-59	4.51E-32	NA	2.2E+02	2.2E+02	2.2E+02	2.2E+02	2.2E+02	2.2E+00	1.7E+02	5.9E+01	1.2E+01	7												
Fr221	5.12E-05	NA	5.0E+02	5.0E+02	5.0E+02	5.0E+02	5.0E+02	5.0E+00	1.5E+03	5.0E+02	1.4E+02	8												
Fr223	2.82E-04	NA	5.0E+02	5.0E+02	5.0E+02	5.0E+02	5.0E+02	5.0E+00	1.5E+03	5.0E+02	1.4E+02	8												
Gd152	2.72E-11	NA	2.4E+02	2.4E+02	2.4E+02	2.4E+02	2.4E+02	2.4E+00	2.2E+02	6.4E+01	1.1E+14	7												
Gd153	2.01E-08	NA	2.4E+02	2.4E+02	2.4E+02	2.4E+02	2.4E+02	2.4E+00	2.4E+02	6.4E+01	6.6E+01	7												
H 3	4.96E+04	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.2E+01	1												
Hf-181	7.80E-34	NA	4.5E+02	4.5E+02	4.5E+02	4.5E+02	4.5E+02	4.5E+00	1.3E+02	1.2E+01	8													
Ho166m	2.70E-03	NA	2.5E+02	2.5E+02	2.5E+02	2.5E+02	2.5E+02	2.5E+00	1.3E+03	7.3E+01	3.1E+03	7												
I129	1.30E+03	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00	6.0E-03	1.6E+07	2												
I131	0.00E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00	6.0E-03	2.2E+02	2												
In114	1.89E-51	NA	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+00	1.0E+00	3.9E+02	1.0E+02	2.3E-06	8											
In114m	1.97E-51	NA	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+00	1.0E+00	3.9E+02	1.0E+02	1.4E-01	8											
In115	5.78E-09	NA	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+00	1.0E+00	3.9E+02	1.0E+02	5.1E+15	8											
In115m	0.00E+00	NA	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+02	3.9E+00	1.0E+00	3.9E+02	1.0E+02	5.1E-04	8											
K-40	1.92E+03	NA	1.5E+01	1.5E+01	1.5E+01	1.5E+01	1.5E+01	1.5E+00	1.5E+01	1.5E+01	1.3E+09	5												
Kr81	5.30E-06	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.1E+05	1												
Kr85	1.16E+06	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.1E+01	1												
La138	0.00E+00	NA	1.2E+03	1.2E+03	1.2E+03	1.2E+03	1.2E+03	1.2E+00	1.2E+03	1.2E+03	1.4E+11	8												
La140	2.65E-102	NA	1.2E+03	1.2E+03	1.2E+03	1.2E+03	1.2E+03	1.2E+00	1.2E+03	1.2E+03	4.6E-03	8												
Mn-54	1.93E-05	NA	5.0E+01	5.0E+01	5.0E+01	5.0E+01	5.0E+01	5.0E+00	5.0E+01	5.0E+01	8.6E-01	6												

Table B-2. (continued)

Constituent	Organic Carbon			Operations Layer K <sub>d</sub> (mL/g)			Alluvium K <sub>d</sub> (mL/g)			Vadose Zone Weighted Average K <sub>d</sub> (mL/g)			Vadose Zone Basalt K <sub>d</sub> (mL/g)			Clay Materials K <sub>d</sub> (mL/g)			Interbeds Materials K <sub>d</sub> (mL/g)			Vadose Zone Surrogates		
	Design Inventory (C <sub>Dl</sub> ) (pCi/kg or mg/kg)	Partition Coefficient (K <sub>oc</sub> ) (mL/g)	Waste Soils K <sub>d</sub> (mL/g)	Operations Layer K <sub>d</sub> (mL/g)	Alluvium K <sub>d</sub> (mL/g)	Average K <sub>d</sub> (mL/g)	Vadose Zone Weighted Average K <sub>d</sub> (mL/g)	Vadose Zone Basalt K <sub>d</sub> (mL/g)	Clay Materials K <sub>d</sub> (mL/g)	Interbeds Materials K <sub>d</sub> (mL/g)	Vadose Zone Surrogates													
Nb92	6.35E-16	NA	1.0E+02	1.0E+02	9.0E+02	1.0E+02	0.0E+00	3.2E+01	3.7E+07	7														
Nb93m	1.35E+01	NA	1.0E+02	1.0E+02	9.0E+02	1.0E+02	0.0E+00	3.2E+01	1.4E+01	7														
Nb94	8.83E-03	NA	1.0E+02	1.0E+02	9.0E+02	1.0E+02	0.0E+00	3.2E+01	2.0E+04	7														
Nb95	4.80E-30	NA	1.0E+02	1.0E+02	9.0E+02	1.0E+02	0.0E+00	3.2E+01	9.6E-02	7														
Nb95m	1.84E-32	NA	1.0E+02	1.0E+02	9.0E+02	1.0E+02	0.0E+00	3.2E+01	9.9E-03	7														
Nd144	3.27E-07	NA	2.4E+02	2.4E+02	2.4E+02	2.4E+02	0.0E+00	6.4E+01	2.1E+15	7														
Nd147	0.00E+00	NA	2.4E+02	2.4E+02	2.4E+02	2.4E+02	0.0E+00	6.4E+01	3.0E+02	7														
Np235	6.80E-08	NA	8.0E+00	8.0E+00	8.0E+00	8.0E+00	0.0E+00	8.0E+01	1.1E+00	5														
Np236	6.93E-05	NA	8.0E+00	8.0E+00	8.0E+00	8.0E+00	0.0E+00	8.0E+01	1.2E+05	5														
Np237	6.43E+02	NA	8.0E+00	8.0E+00	8.0E+00	8.0E+00	0.0E+00	5.5E+01	2.1E+06	5														
Np238	2.18E-04	NA	8.0E+00	8.0E+00	8.0E+00	8.0E+00	0.0E+00	8.0E+01	5.8E-03	5														
Np239	3.34E-01	NA	8.0E+00	8.0E+00	8.0E+00	8.0E+00	0.0E+00	8.0E+01	6.5E-03	5														
Np240	2.79E-11	NA	8.0E+00	8.0E+00	8.0E+00	8.0E+00	0.0E+00	5.5E+01	1.2E-04	5														
Np240m	2.54E-08	NA	8.0E+00	8.0E+00	8.0E+00	8.0E+00	0.0E+00	5.5E+01	2.4E+00	1.4E-05	5													
Pa231	6.98E-02	NA	5.5E+02	5.5E+02	5.5E+02	5.5E+02	0.0E+00	5.5E+02	1.6E+02	3.3E+04	8													
Pa233	4.36E+01	NA	5.5E+02	5.5E+02	5.5E+02	5.5E+02	0.0E+00	5.5E+02	1.6E+02	7.4E-02	8													
Pa234	2.74E-03	NA	5.5E+02	5.5E+02	5.5E+02	5.5E+02	0.0E+00	5.5E+02	1.6E+02	7.6E-04	8													
Pa234m	1.71E+00	NA	5.5E+02	5.5E+02	5.5E+02	5.5E+02	0.0E+00	5.5E+02	1.6E+02	2.2E-06	8													
Pb209	4.85E-05	NA	1.0E+02	1.0E+02	1.0E+02	1.0E+02	0.0E+00	1.0E+02	3.0E+01	3.7E-04	7													
Pb210	1.09E-03	NA	1.0E+02	1.0E+02	1.0E+02	1.0E+02	0.0E+00	1.0E+02	3.0E+01	2.2E+01	7													
Pb211	1.83E-02	NA	1.0E+02	1.0E+02	1.0E+02	1.0E+02	0.0E+00	1.0E+02	3.0E+01	6.9E-05	7													
Pb212	5.53E-01	NA	1.0E+02	1.0E+02	1.0E+02	1.0E+02	0.0E+00	1.0E+02	3.0E+01	1.2E-03	7													
Pb214	5.62E-03	NA	1.0E+02	1.0E+02	1.0E+02	1.0E+02	0.0E+00	1.0E+02	3.0E+01	5.1E-05	7													
Pd107	6.12E+00	NA	5.5E+01	5.5E+01	5.5E+01	5.5E+01	0.0E+00	5.5E+01	2.7E+02	5.5E+01	6													
Pm146	5.81E+00	NA	2.4E+02	2.4E+02	2.4E+02	2.4E+02	0.0E+00	2.4E+02	6.4E+01	5.5E+00	7													
Pm147	3.82E+05	NA	2.4E+02	2.4E+02	2.4E+02	2.4E+02	0.0E+00	2.4E+02	6.4E+01	2.6E+00	7													
Pm148	3.97E-56	NA	2.4E+02	2.4E+02	2.4E+02	2.4E+02	0.0E+00	2.4E+02	6.4E+01	1.5E-02	7													
Pm148m	8.23E-55	NA	2.4E+02	2.4E+02	2.4E+02	2.4E+02	0.0E+00	2.4E+02	6.4E+01	1.1E-01	7													
Po210	1.02E-03	NA	1.5E+02	1.5E+02	1.5E+02	1.5E+02	0.0E+00	1.5E+02	3.0E+03	5.7E+01	7													
Po211	6.84E-07	NA	1.5E+02	1.5E+02	1.5E+02	1.5E+02	0.0E+00	1.5E+02	3.0E+03	5.7E+01	1.6E-08	7												
Po212	3.28E-01	NA	1.5E+02	1.5E+02	1.5E+02	1.5E+02	0.0E+00	1.5E+02	3.0E+03	5.7E+01	9.7E-15	7												
Po213	4.34E-05	NA	1.5E+02	1.5E+02	1.5E+02	1.5E+02	0.0E+00	1.5E+02	3.0E+03	5.7E+01	1.3E-13	7												
Po214	5.62E-03	NA	1.5E+02	1.5E+02	1.5E+02	1.5E+02	0.0E+00	1.5E+02	3.0E+03	5.7E+01	5.2E-12	7												
Po215	1.83E-02	NA	1.5E+02	1.5E+02	1.5E+02	1.5E+02	0.0E+00	1.5E+02	3.0E+03	5.7E+01	5.6E-11	7												
Po216	5.53E-01	NA	1.5E+02	1.5E+02	1.5E+02	1.5E+02	0.0E+00	1.5E+02	3.0E+03	5.7E+01	4.8E-09	7												
Po218	5.62E-03	NA	1.5E+02	1.5E+02	1.5E+02	1.5E+02	0.0E+00	1.5E+02	3.0E+03	5.7E+01	5.8E-06	7												
Pr143	0.00E+00	NA	2.4E+02	2.4E+02	2.4E+02	2.4E+02	0.0E+00	2.4E+02	6.4E+01	3.7E+02	7													
Pr144	1.77E+00	NA	2.4E+02	2.4E+02	2.4E+02	2.4E+02	0.0E+00	2.4E+02	6.4E+01	3.3E-05	7													
Pr144m	2.53E-02	NA	2.4E+02	2.4E+02	2.4E+02	2.4E+02	0.0E+00	2.4E+02	6.4E+01	1.4E-05	7													
Pu236	5.53E-03	NA	1.4E+02	1.4E+02	1.4E+02	1.4E+02	0.0E+00	1.4E+02	2.2E+01	2.9E+00	7													
Pu237	1.21E-55	NA	1.4E+02	1.4E+02	1.4E+02	1.4E+02	0.0E+00	1.4E+02	2.2E+01	1.2E-01	7													
Pu238	2.33E+05	NA	1.4E+02	1.4E+02	1.4E+02	1.4E+02	0.0E+00	1.4E+02	2.2E+01	8.8E+01	7													

Table B-2. (continued)

Constituent	Organic Carbon			Operations Layer K <sub>d</sub> (mL/g)			Clean Alluvium K <sub>d</sub> (mL/g)			Vadose Zone Weighted Average K <sub>d</sub> (mL/g)			Vadose Zone Basalt K <sub>d</sub> (mL/g)			Clay Materials K <sub>d</sub> (mL/g)			Interbeds Materials K <sub>d</sub> (mL/g)			Vadose Zone Surrogates		
	Design Inventory (C <sub>Dl</sub> ) (pCi/kg or mg/kg)	Partition Coefficient (K <sub>oc</sub> ) (mL/g)	Waste Soils K <sub>d</sub> (mL/g)	Operations Layer K <sub>d</sub> (mL/g)	Clean Alluvium K <sub>d</sub> (mL/g)	Average K <sub>d</sub> (mL/g)	Vadose Zone Weighted Average K <sub>d</sub> (mL/g)	Vadose Zone Basalt K <sub>d</sub> (mL/g)	Clay Materials K <sub>d</sub> (mL/g)	Interbeds Materials K <sub>d</sub> (mL/g)	Vadose Zone Surrogates													
Pu239	6.66E+03	NA	1.4E+02	1.4E+02	1.4E+02	1.7E+03	2.2E+01	0.0E+00	2.8E+01	2.4E+04	7													
Pu240	1.50E+03	NA	1.4E+02	1.4E+02	1.4E+02	1.7E+03	2.2E+01	0.0E+00	2.8E+01	6.5E+03	7													
Pu241	6.39E+04	NA	1.4E+02	1.4E+02	1.4E+02	1.7E+03	2.2E+01	0.0E+00	2.8E+01	1.4E+01	7													
Pu242	2.41E-01	NA	1.4E+02	1.4E+02	1.4E+02	1.7E+03	2.2E+01	0.0E+00	2.8E+01	3.8E+05	7													
Pu243	6.39E-13	NA	1.4E+02	1.4E+02	1.4E+02	1.7E+03	2.2E+01	0.0E+00	2.8E+01	5.7E-04	7													
Pu244	2.54E-08	NA	1.4E+02	1.4E+02	1.4E+02	1.7E+03	2.2E+01	0.0E+00	2.8E+01	8.3E+07	7													
Pu246	1.38E-22	NA	1.4E+02	1.4E+02	1.4E+02	1.7E+03	2.2E+01	0.0E+00	2.8E+01	3.0E-02	7													
Ra222	1.17E-113	NA	1.0E+02	1.0E+02	1.0E+02	1.0E+02	1.0E+02	0.0E+00	8.1E+01	1.2E-06	7													
Ra223	2.03E-02	NA	1.0E+02	1.0E+02	1.0E+02	1.0E+02	1.0E+02	0.0E+00	8.1E+01	3.1E-02	7													
Ra224	5.53E-01	NA	1.0E+02	1.0E+02	1.0E+02	9.1E+03	1.0E+02	0.0E+00	8.1E+01	1.0E-02	7													
Ra225	5.12E-05	NA	1.0E+02	1.0E+02	1.0E+02	9.1E+03	1.0E+02	0.0E+00	8.1E+01	4.1E-02	7													
Ra226	4.74E+02	NA	1.0E+02	1.0E+02	1.0E+02	9.1E+03	1.0E+02	0.0E+00	8.1E+01	1.6E+03	7													
Ra228	1.52E-07	NA	1.0E+02	1.0E+02	1.0E+02	9.1E+03	1.0E+02	0.0E+00	8.1E+01	5.8E+00	7													
Rb86	0.00E+00	NA	5.5E+01	5.5E+01	5.5E+01	5.5E+01	2.7E+02	0.0E+00	1.6E+01	5.1E-02	6													
Rb87	1.11E-02	NA	5.5E+01	5.5E+01	5.5E+01	5.5E+01	2.7E+02	0.0E+00	1.6E+01	4.7E+10	6													
Rh102	2.97E-02	NA	5.2E+01	5.2E+01	5.2E+01	5.2E+01	5.2E+01	0.0E+00	1.4E+01	2.9E+00	6													
Rh103m	2.83E-55	NA	5.2E+01	5.2E+01	5.2E+01	5.2E+01	5.2E+01	0.0E+00	1.4E+01	1.1E-04	6													
Rh106	1.14E+01	NA	5.2E+01	5.2E+01	5.2E+01	5.2E+01	5.2E+01	0.0E+00	1.4E+01	9.5E-07	6													
Rn218	1.26E-113	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.1E-09	1													
Rn219	2.03E-02	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E-07	1													
Rn220	5.53E-01	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.8E-06	1													
Rn222	6.21E-03	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E-02	1													
Ru103	2.01E-26	NA	5.5E+01	5.5E+01	5.5E+01	5.5E+01	5.5E+01	0.0E+00	0.0E+00	1.9E+01	7													
Ru106	1.21E+01	NA	5.5E+01	5.5E+01	5.5E+01	5.5E+01	5.5E+01	0.0E+00	0.0E+00	1.9E+01	7													
Sb124	2.07E-37	NA	5.0E+01	5.0E+01	5.0E+01	5.0E+01	5.0E+01	0.0E+00	0.0E+00	1.5E+01	6													
Sb125	9.27E+03	NA	5.0E+01	5.0E+01	5.0E+01	5.0E+01	5.0E+01	0.0E+00	0.0E+00	1.5E+01	6													
Sb126	2.06E+01	NA	5.0E+01	5.0E+01	5.0E+01	5.0E+01	5.0E+01	0.0E+00	0.0E+00	1.5E+01	6													
Sb126m	1.47E+02	NA	5.0E+01	5.0E+01	5.0E+01	5.0E+01	5.0E+01	0.0E+00	0.0E+00	1.5E+01	6													
Sc-46	2.85E-17	NA	3.1E+02	3.1E+02	3.1E+02	3.1E+02	3.1E+02	0.0E+00	8.3E+01	2.3E-01	7													
Se79	1.66E+02	NA	4.0E+00	4.0E+00	4.0E+00	7.4E+02	4.0E+00	0.0E+00	5.5E+00	6.5E+04	6													
Sm146	4.26E-07	NA	2.4E+02	2.4E+02	2.4E+02	1.3E+03	2.4E+02	0.0E+00	7.1E+01	1.0E+08	7													
Sm147	4.10E-03	NA	2.4E+02	2.4E+02	2.4E+02	1.3E+03	2.4E+02	0.0E+00	7.1E+01	1.1E+11	7													
Sm148	1.01E-09	NA	2.4E+02	2.4E+02	2.4E+02	1.3E+03	2.4E+02	0.0E+00	7.1E+01	7.0E+15	7													
Sm149	5.12E-09	NA	2.4E+02	2.4E+02	2.4E+02	1.3E+03	2.4E+02	0.0E+00	7.1E+01	1.0E+16	7													
Sm151	3.38E+05	NA	2.4E+02	2.4E+02	2.4E+02	1.3E+03	2.4E+02	0.0E+00	7.1E+01	9.0E+01	7													
Sn117m	0.00E+00	NA	1.3E+02	1.3E+02	1.3E+02	1.3E+02	1.3E+02	0.0E+00	1.3E+02	3.7E-02	7													
Sn119m	1.48E-04	NA	1.3E+02	1.3E+02	1.3E+02	1.3E+02	1.3E+02	0.0E+00	1.3E+02	8.0E-01	7													
Sn121m	2.69E+01	NA	1.3E+02	1.3E+02	1.3E+02	1.3E+02	1.3E+02	0.0E+00	1.3E+02	5.5E+01	7													
Sn123	8.42E-14	NA	1.3E+02	1.3E+02	1.3E+02	1.3E+02	1.3E+02	0.0E+00	1.3E+02	3.5E-01	7													
Sn125	0.00E+00	NA	1.3E+02	1.3E+02	1.3E+02	1.3E+02	1.3E+02	0.0E+00	1.3E+02	2.6E-02	7													
Sn126	1.47E+02	NA	1.3E+02	1.3E+02	1.3E+02	1.3E+02	1.3E+02	0.0E+00	1.3E+02	1.0E+05	7													
Sr89	5.99E-41	NA	1.2E+01	2.0E+02	1.2E+01	2.0E+02	1.2E+01	0.0E+00	4.5E+00	1.4E+01	6													

Table B-2. (continued)

Constituent	Organic Carbon			Operations Layer K <sub>d</sub> (mL/g)	Clean Alluvium K <sub>d</sub> (mL/g)	Clay Materials K <sub>d</sub> (mL/g)	Interbeds Materials K <sub>d</sub> (mL/g)	Vadose Zone Basalt K <sub>d</sub> (mL/g)	Average K <sub>d</sub> (mL/g)	Vadose Zone Weighted Average K <sub>d</sub> (mL/g)	Half-Life (yr)	Surrogates	
	Design Inventory (C <sub>Dl</sub> ) (pCi/kg or mg/kg)	Partition Coefficient (K <sub>oc</sub> ) (mL/g)	Waste Soils K <sub>d</sub> (mL/g)										
Sr90	2.29E+07	NA	1.2E+01	2.4E+01	2.0E+02	1.2E+01	0.0E+00	4.5E+00	2.9E+01	2.9E+00	6		
Tb160	3.18E-31	NA	2.4E+02	2.4E+02	2.4E+02	2.4E+02	0.0E+00	6.4E+01	2.0E+01	2.0E+01	7		
Tb161	0.00E+00	NA	2.4E+02	2.4E+02	2.4E+02	2.4E+02	0.0E+00	6.4E+01	1.9E+02	1.9E+02	7		
Tc 98	1.77E-04	NA	2.0E-01	2.0E-01	2.0E-01	2.0E-01	0.0E+00	2.0E-01	5.8E-02	4.2E+06	3		
Tc 99	5.76E+03	NA	2.0E-01	2.0E-01	2.0E-01	2.0E-01	0.0E+00	5.8E-02	2.1E+05	3			
Tel23	4.52E-12	NA	1.3E+02	1.3E+02	1.3E+02	1.3E+02	0.0E+00	3.7E+01	1.0E+13	7			
Tel123m	2.95E-20	NA	1.3E+02	1.3E+02	1.3E+02	1.3E+02	0.0E+00	7.2E+02	1.3E+02	3.3E+01	7		
Tel25m	2.27E+03	NA	1.3E+02	1.3E+02	1.3E+02	1.3E+02	0.0E+00	7.2E+02	1.3E+02	1.6E+01	7		
Tel127	9.36E-17	NA	1.3E+02	1.3E+02	1.3E+02	1.3E+02	0.0E+00	7.2E+02	1.3E+02	1.1E+03	7		
Tel127m	9.50E-17	NA	1.3E+02	1.3E+02	1.3E+02	1.3E+02	0.0E+00	7.2E+02	1.3E+02	3.0E+01	7		
Tel129	6.75E-68	NA	1.3E+02	1.3E+02	1.3E+02	1.3E+02	0.0E+00	7.2E+02	1.3E+02	1.3E+04	7		
Tel129m	1.07E-67	NA	1.3E+02	1.3E+02	1.3E+02	1.3E+02	0.0E+00	7.2E+02	1.3E+02	9.2E+02	7		
Th226	2.18E-114	NA	1.0E+02	1.0E+02	1.0E+02	1.0E+02	0.0E+00	1.0E+02	1.0E+02	5.9E-05	7		
Th227	1.82E-02	NA	1.0E+02	1.0E+02	1.0E+02	1.0E+02	0.0E+00	1.0E+02	1.0E+02	5.1E-02	7		
Th228	3.29E+01	NA	1.0E+02	1.0E+02	1.0E+02	1.0E+02	0.0E+00	1.0E+02	1.0E+02	1.9E+00	7		
Th229	5.12E-05	NA	1.0E+02	1.0E+02	1.0E+02	1.0E+02	0.0E+00	1.0E+02	1.0E+02	3.6E+01	7		
Th230	1.73E+02	NA	1.0E+02	1.0E+02	1.0E+02	1.0E+02	0.0E+00	1.0E+02	1.0E+02	3.6E+01	7		
Th231	1.61E+02	NA	1.0E+02	1.0E+02	1.0E+02	1.0E+02	0.0E+00	1.0E+02	1.0E+02	3.6E+01	7		
Th232	1.56E+02	NA	1.0E+02	1.0E+02	1.0E+02	1.0E+02	0.0E+00	1.0E+02	1.0E+02	3.6E+01	7		
Th234	1.71E+00	NA	1.0E+02	1.0E+02	1.0E+02	1.0E+02	0.0E+00	1.0E+02	1.0E+02	3.6E+01	7		
Tl207	1.83E-02	NA	1.0E+02	1.0E+02	1.0E+02	1.0E+02	0.0E+00	1.0E+02	1.0E+02	2.9E-03	7		
Tl208	1.98E-01	NA	1.0E+02	1.0E+02	1.0E+02	1.0E+02	0.0E+00	1.0E+02	1.0E+02	1.4E+10	7		
Tl209	1.05E-06	NA	1.0E+02	1.0E+02	1.0E+02	1.0E+02	0.0E+00	1.0E+02	1.0E+02	6.6E-02	7		
Tm170	6.38E-23	NA	2.4E+02	2.4E+02	2.4E+02	2.4E+02	0.0E+00	2.4E+02	2.4E+02	2.7E+01	7		
Tm171	1.59E-09	NA	2.4E+02	2.4E+02	2.4E+02	2.4E+02	0.0E+00	2.4E+02	2.4E+02	6.4E+01	7		
U230	0.00E+00	NA	6.0E+00	6.0E+00	6.0E+00	6.0E+00	0.0E+00	6.0E+00	6.0E+00	2.0E+00	4		
U232	5.35E-01	NA	6.0E+00	6.0E+00	6.0E+00	6.0E+00	0.0E+00	6.0E+00	6.0E+00	7.2E+01	4		
U233	2.56E-02	NA	6.0E+00	6.0E+00	6.0E+00	6.0E+00	0.0E+00	6.0E+00	6.0E+00	1.6E+05	4		
U234	6.03E+03	NA	6.0E+00	6.0E+00	6.0E+00	6.0E+00	0.0E+00	6.0E+00	6.0E+00	2.5E+05	4		
U235	1.10E+02	NA	6.0E+00	6.0E+00	6.0E+00	6.0E+00	0.0E+00	6.3E+01	6.0E+00	7.0E+08	4		
U236	2.02E+02	NA	6.0E+00	6.0E+00	6.0E+00	6.0E+00	0.0E+00	6.3E+01	6.0E+00	2.3E+07	4		
U237	0.00E+00	NA	6.0E+00	6.0E+00	6.0E+00	6.0E+00	0.0E+00	6.3E+01	6.0E+00	1.8E-02	4		
Xe127	1.58E-69	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E-01	1		
Xe129m	0.00E+00	NA	1.95E+03	NA	6.0E+00	6.0E+00	0.0E+00	6.3E+01	6.0E+00	0.0E+00	2.2E-02	1	
U238	2.54E-08	NA	6.0E+00	6.0E+00	6.0E+00	6.0E+00	0.0E+00	6.3E+01	6.0E+00	2.0E+00	4.5E+09	4	
U240	1.7E+02	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.6E-03	4		
Xe133	0.00E+00	NA	1.7E+02	NA	1.7E+02	1.7E+02	0.0E+00	1.7E+02	1.7E+02	1.4E-02	1		
Y90	2.29E+07	NA	1.0E+03	NA	1.0E+03	1.0E+03	0.0E+00	1.0E+03	1.0E+03	5.1E+01	7		
Xe131m	2.69E-109	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.3E-02	1		
Xe133	0.00E+00	NA	1.6E+01	NA	1.6E+01	1.6E+01	0.0E+00	1.6E+01	1.6E+01	1.4E-02	1		
Zn65	2.70E-06	NA	6.0E+02	NA	6.0E+02	6.0E+02	0.0E+00	6.0E+02	6.0E+02	7.3E-03	7		
Zr93	8.57E+02	NA	6.0E+02	NA	6.0E+02	6.0E+02	0.0E+00	6.0E+02	6.0E+02	1.5E+06	8		

Table B-2. (continued)

Design Constituent	Inventory (C <sub>D</sub> ) (pCi/kg or mg/kg)	Organic Carbon Partition Coefficient (K <sub>oc</sub> ) (mL/g)	Waste Soils K <sub>d</sub> (mL/g)	Operations Layer K <sub>d</sub> (mL/g)	Clean Alluvium K <sub>d</sub> (mL/g)	Clay Materials K <sub>d</sub> (mL/g)	Interbeds Materials K <sub>d</sub> (mL/g)	Vadose Zone Basalt K <sub>d</sub> (mL/g)	Vadose Zone Weighted Average K <sub>d</sub> (mL/g)	Half-Life (yr)	Vadose Zone Surrogates
											Z-95
1,1,1-Trichloroethane	2.93E-22	NA	6.0E+02	6.0E+02	3.3E+03	6.0E+02	0.0E+00	1.8E+02	1.8E+01	8	
1,1,2,2-Tetrachloroethane	1.57E-02	1.4E+02	3.4E-01	3.4E-01	0.0E+00	6.8E-02	0.0E+00	4.5E-02	3.0E+00	2	
1,1,2,2,2-Pentachloroethane	4.95E-05	7.9E+01	2.0E-01	2.0E-01	0.0E+00	4.0E-02	0.0E+00	2.6E-02	1.5E-01	2	
1,1,2-Trichloroethane	2.42E-04	7.5E+01	1.9E-01	1.9E-01	0.0E+00	3.8E-02	0.0E+00	2.5E-02	8.6E+01	2	
1,1-Dichloroethane	2.34E-03	5.3E+01	1.3E-01	1.3E-01	0.0E+00	2.7E-02	0.0E+00	1.8E-02	2.8E-01	2	
1,1-Dichloroethene	1.48E-03	6.5E+01	1.6E-01	1.6E-01	0.0E+00	3.3E-02	0.0E+00	2.2E-02	2.7E-01	2	
1,1,4-Trichlorobenzene	1.14E-02	1.7E+03	4.1E+00	4.1E+00	0.0E+00	4.1E+00	0.0E+00	5.8E-01	5.5E-01	3	
1,1,4-Dichlorobenzene	1.14E-02	3.8E+02	9.5E-01	9.5E-01	0.0E+00	1.9E-01	0.0E+00	1.1E-02	1.1E-01	3	
1,1,2-Dichloroethane	5.38E-06	3.8E+01	9.5E-02	9.5E-02	0.0E+00	1.9E-02	0.0E+00	1.3E-02	6.4E-01	2	
1,1,2-Dichloroethene (total)	3.24E-04	2.9E+00	7.2E-03	7.2E-03	0.0E+00	1.4E-03	0.0E+00	9.6E-04	1.1E+00	1	
1,1,3-Dichlorobenzene	1.14E-02	3.8E+02	9.5E-01	9.5E-01	0.0E+00	1.9E-01	0.0E+00	5.8E-01	5.8E-01	3	
1,1,4-Dichlorobenzene	4.50E-01	6.2E+02	1.5E+00	1.5E+00	0.0E+00	3.1E-01	0.0E+00	2.1E-01	5.8E-01	3	
1,4-Dioxane	1.88E-05	1.1E+01	2.8E-02	2.8E-02	0.0E+00	5.5E-03	0.0E+00	3.7E-03	2.8E-01	1	
2,4,5-Trichlorophenol	4.46E-02	1.6E+03	4.0E+00	4.0E+00	0.0E+00	4.0E+00	0.0E+00	5.3E-01	9.8E-01	3	
2,4,6-Trichlorophenol	1.83E-02	3.8E+02	9.5E-01	9.5E-01	0.0E+00	9.5E-01	0.0E+00	1.3E-01	2.5E+00	3	
2,4-Dichlorophenol	2.16E-02	1.5E+02	3.7E-01	3.7E-01	0.0E+00	7.4E-02	0.0E+00	4.9E-02	1.3E-01	2	
2,4-Dimethylphenol	1.83E-02	2.1E+02	5.2E-01	5.2E-01	0.0E+00	5.2E-01	0.0E+00	7.0E-02	2.2E-02	3	
2,4-Dinitrophenol	5.09E-02	1.0E-02	2.5E-05	2.5E-05	0.0E+00	5.0E-06	0.0E+00	3.3E-06	2.8E-02	1	
2,4-Dinitrotoluene	1.14E-02	9.6E+01	2.4E-01	2.4E-01	0.0E+00	4.8E-02	0.0E+00	3.2E-02	5.0E-01	2	
2,6-Dinitrotoluene	2.07E-02	6.9E+01	1.7E-01	1.7E-01	0.0E+00	3.5E-02	0.0E+00	2.3E-02	5.0E-01	2	
2-Butanone	2.47E-02	4.5E+00	1.1E-02	1.1E-02	0.0E+00	1.1E-02	0.0E+00	2.3E-03	1.5E-03	NA	
2-Chloronaphthalene	1.14E-02	1.6E+03	3.9E+00	3.9E+00	0.0E+00	7.8E-01	0.0E+00	5.2E-01	1.9E-01	3	
2-Chlorophenol	1.83E-02	4.0E+02	1.0E+00	1.0E+00	0.0E+00	2.0E-01	0.0E+00	1.3E-01	6.8E-03	3	
2-Hexanone	2.70E-03	1.5E+01	3.8E-02	3.8E-02	0.0E+00	7.6E-03	0.0E+00	5.0E-03	NA	1	
2-Methylnaphthalene	5.12E-01	8.5E+03	2.1E+01	2.1E+01	0.0E+00	4.3E+00	0.0E+00	2.8E+00	NA	5	
2-Methylphenol	2.06E-02	9.1E+01	2.3E-01	2.3E-01	0.0E+00	4.6E-02	0.0E+00	3.0E-02	6.8E-02	2	
2-Nitroaniline	2.72E-02	1.7E+01	4.2E-02	4.2E-02	0.0E+00	4.2E-02	0.0E+00	8.5E-03	5.7E-03	NA	
2-Nitrophenol	1.83E-02	3.9E+01	9.7E-02	9.7E-02	0.0E+00	1.9E-02	0.0E+00	1.3E-02	5.8E-02	2	
3,3'-Dichlorobenzidine	1.14E-02	7.2E+02	1.8E+00	1.8E+00	0.0E+00	3.6E-01	0.0E+00	5.1E-01	2.4E-01	3	
3-Methyl Butanal	2.23E-04	NA	NA	NA	0.0E+00	NA	NA	NA	NA	1	
3-Nitroaniline	2.72E-02	1.7E+01	4.2E-02	4.2E-02	0.0E+00	8.5E-03	0.0E+00	5.7E-03	NA	1	
4,6-Dinitro-2-methylphenol	4.46E-02	6.3E+02	1.6E+00	1.6E+00	0.0E+00	3.2E-01	0.0E+00	2.1E-01	1.1E-01	3	
4-Bromophenyl-phenylether	1.14E-02	1.7E+04	4.3E+01	4.3E+01	0.0E+00	8.5E+00	0.0E+00	5.7E+00	NA	6	
4-Chloro-3-methylphenol	1.83E-02	5.0E+01	1.3E-01	1.3E-01	0.0E+00	2.5E-02	0.0E+00	1.7E-02	NA	2	
4-Chloroaniline	4.08E-02	6.6E+01	1.7E-01	1.7E-01	0.0E+00	3.3E-02	0.0E+00	2.2E-02	NA	2	
4-Chlorophenyl-phenylether	1.14E-02	3.1E+03	7.8E+00	7.8E+00	0.0E+00	1.6E+00	0.0E+00	1.0E+00	NA	3	
4-Methyl-2-Pentanone	2.96E-02	1.3E+02	3.4E-01	3.4E-01	0.0E+00	6.7E-02	0.0E+00	4.5E-02	3.8E-02	2	
4-Methylphenol	3.86E-02	8.1E+01	2.0E-01	2.0E-01	0.0E+00	4.0E-02	0.0E+00	2.7E-02	3.8E-02	2	
Acenaphthene	2.02E-01	7.1E+03	1.8E+01	1.8E+01	0.0E+00	3.5E+00	0.0E+00	2.4E+00	3.1E-01	4	
4-Nitroaniline	2.07E-02	2.0E+03	5.0E+00	5.0E+00	0.0E+00	6.7E-01	0.0E+00	5.7E-01	NA	1	
4-Nitrophenol	5.16E-02	3.9E+01	9.7E-02	9.7E-02	0.0E+00	1.9E-02	0.0E+00	1.3E-02	1.5E-02	2	
Acenaphthylene	6.20E-01	5.8E+01	1.4E-03	1.4E-03	0.0E+00	3.0E+00	0.0E+00	2.4E+00	2.4E+00	4	
Acetone	6.20E-01	5.8E+01	1.4E-03	1.4E-03	0.0E+00	2.9E+00	0.0E+00	2.0E+00	2.0E+00	3	

Table B-2. (continued)

Constituent	Organic Carbon			Operations Layer K <sub>d</sub> (mL/g)			Clean Alluvium K <sub>d</sub> (mL/g)			Vadose Zone Weighted Average K <sub>d</sub> (mL/g)			Vadose Zone Basalt K <sub>d</sub> (mL/g)		Half-Life (yr)	Surrogates
	Design Inventory (C <sub>Dl</sub> ) (pCi/kg or mg/kg)	Partition Coefficient (K <sub>oc</sub> ) (mL/g)	Waste Soils K <sub>d</sub> (mL/g)	Operations Layer K <sub>d</sub> (mL/g)	Clean Alluvium K <sub>d</sub> (mL/g)	Clay Materials K <sub>d</sub> (mL/g)	Interbeds Materials K <sub>d</sub> (mL/g)	Vadose Zone Basalt K <sub>d</sub> (mL/g)	Average K <sub>d</sub> (mL/g)	Vadose Zone Weighted Average K <sub>d</sub> (mL/g)	Average K <sub>d</sub> (mL/g)	Vadose Zone Weighted Average K <sub>d</sub> (mL/g)				
Acetonitrile	1.88E-05	1.6E+01	3.9E-02	3.9E-02	3.9E-02	0.0E+00	7.8E-03	0.0E+00	5.2E-03	4.8E-02	1					
Acrolein	9.06E-06	2.1E+01	5.3E-02	5.3E-02	5.3E-02	0.0E+00	1.1E-02	0.0E+00	7.1E-03	4.2E-02	2					
Acrylonitrile	9.06E-06	8.5E-01	2.1E-03	2.1E-03	2.1E-03	0.0E+00	4.3E-04	0.0E+00	2.8E-04	6.6E-02	1					
Anthracene	3.20E-01	3.0E+04	7.4E+01	7.4E+01	7.4E+01	0.0E+00	1.5E+01	0.0E+00	9.8E+00	1.4E+00	6					
Aramite	1.15E-04	1.6E+04	3.9E+01	3.9E+01	3.9E+01	0.0E+00	7.8E+00	0.0E+00	5.2E+00	NA	6					
Aroclor-1016	7.69E-03	3.3E+04	8.3E+01	8.3E+01	8.3E+01	0.0E+00	1.7E+01	0.0E+00	1.1E+01	7.0E+00	6					
Aroclor-1254	1.28E-01	2.0E+05	5.0E+02	5.0E+02	5.0E+02	0.0E+00	1.0E+02	0.0E+00	6.7E+01	7.0E+00	7					
Aroclor-1260	7.21E-01	2.9E+05	7.3E+02	7.3E+02	7.3E+02	0.0E+00	1.5E+02	0.0E+00	9.7E+01	7.0E+00	8					
Aroclor-1268	6.22E-02	3.3E+04	8.3E+01	8.3E+01	8.3E+01	0.0E+00	1.7E+01	0.0E+00	1.1E+01	7.0E+00	6					
Benzene	6.03E-01	6.2E+01	1.6E-01	1.6E-01	1.6E-01	0.0E+00	3.1E-02	0.0E+00	2.1E-02	4.4E-01	2					
Benzidine	2.91E-04	1.5E+02	3.9E-01	3.9E-01	3.9E-01	0.0E+00	7.7E-02	0.0E+00	5.2E-02	2.7E-02	2					
Benzo(a)anthracene	2.53E-01	4.0E+05	1.0E+03	1.0E+03	1.0E+03	0.0E+00	2.0E+02	0.0E+00	1.3E+02	2.1E+00	8					
Benzo(a)pyrene	1.05E-01	1.0E+06	2.6E+03	2.6E+03	2.6E+03	0.0E+00	5.1E+02	0.0E+00	3.4E+02	1.6E+00	8					
Benzo(b)fluoranthene	1.79E-01	1.2E+06	3.1E+03	3.1E+03	3.1E+03	0.0E+00	6.2E+02	0.0E+00	4.1E+02	2.7E+00	8					
Benzo(g,h,i)perylene	1.14E-02	3.9E+06	9.6E+03	9.6E+03	9.6E+03	0.0E+00	1.9E+03	0.0E+00	1.3E+03	3.4E+00	8					
Benzo(k)fluoranthene	1.86E-02	1.2E+06	3.1E+03	3.1E+03	3.1E+03	0.0E+00	6.2E+02	0.0E+00	4.1E+02	8.4E+00	8					
Benzoic acid	8.56E-03	6.0E-01	1.5E-03	1.5E-03	1.5E-03	0.0E+00	3.0E-04	0.0E+00	2.0E-04	1.9E-02	1					
bis(2-Chloroethoxy)methane	1.14E-02	5.5E+00	1.4E-02	1.4E-02	1.4E-02	0.0E+00	2.7E-03	0.0E+00	1.8E-03	NA	1					
bis(2-Chloroethyl)ether	1.14E-02	7.6E+01	1.9E-01	1.9E-01	1.9E-01	0.0E+00	3.8E-02	0.0E+00	2.5E-02	5.8E-01	2					
bis(2-Chloroisopropyl)ether	1.14E-02	6.1E+01	1.5E-01	1.5E-01	1.5E-01	0.0E+00	3.1E-02	0.0E+00	2.0E-02	3.4E-01	2					
bis(2-Ethylhexyl)phthalate	1.47E-01	1.5E+07	3.8E+04	3.8E+04	3.8E+04	0.0E+00	7.6E+03	0.0E+00	5.0E+03	5.5E-01	8					
Butane,1,1,3,4-Tetrachloro-Butylbenzylphthalate	7.89E-03	7.9E+01	2.0E-01	2.0E-01	2.0E-01	0.0E+00	4.0E-02	0.0E+00	2.6E-02	2.6E-02	1.5E-01	2				
Carbazole	3.23E-02	3.4E+03	8.5E+00	8.5E+00	8.5E+00	0.0E+00	8.5E+00	0.0E+00	8.5E+00	1.7E+00	NA	3				
Carbon Disulfide	4.55E-02	4.6E+01	1.1E-01	1.1E-01	1.1E-01	0.0E+00	2.3E-02	0.0E+00	2.3E-02	4.1E-03	2					
Chlorobenzene	6.57E-03	2.2E+02	5.6E-01	5.6E-01	5.6E-01	0.0E+00	1.1E-01	0.0E+00	1.1E-01	7.5E-02	3					
Chloroethane	3.02E-06	1.5E+01	3.7E-02	3.7E-02	3.7E-02	0.0E+00	7.4E-03	0.0E+00	7.4E-03	2.7E-02	1					
Chloromethane	3.53E-04	3.5E+01	8.8E-02	8.8E-02	8.8E-02	0.0E+00	1.8E-02	0.0E+00	1.8E-02	1.2E-02	2					
Chrysene	2.65E-01	4.0E+05	1.0E+03	1.0E+03	1.0E+03	0.0E+00	2.0E+02	0.0E+00	1.3E+02	3.8E+00	8					
Decane, 3,4-Dimethyl	1.61E-04	NA	NA	NA	NA	0.0E+00	NA	0.0E+00	NA	NA	1					
Diacetone alcohol	4.32E+00	1.3E+02	3.4E-01	3.4E-01	3.4E-01	0.0E+00	6.7E-02	0.0E+00	4.5E-02	3.8E-02	2					
Dibenz(a,h)anthracene	1.14E-02	3.8E+06	9.5E+03	9.5E+03	9.5E+03	0.0E+00	1.9E+03	0.0E+00	1.3E+03	3.6E+00	8					
Diethylfuran	3.24E-01	7.8E+03	1.9E+01	1.9E+01	1.9E+01	0.0E+00	3.9E+00	0.0E+00	2.6E+00	4.8E-02	5					
Dimethyl Disulfide	1.14E-02	2.9E+02	7.2E-01	7.2E-01	7.2E-01	0.0E+00	1.4E-01	0.0E+00	9.6E-02	1.6E-01	3					
Eicosane	2.83E-03	NA	NA	NA	NA	0.0E+00	NA	0.0E+00	NA	NA	1					
Ethyl cyanide	1.88E-05	NA	NA	NA	NA	0.0E+00	NA	0.0E+00	NA	NA	1					
Ethyllbenzene	7.81E-02	2.0E+02	5.1E-01	5.1E-01	5.1E-01	0.0E+00	1.0E+00	0.0E+00	6.8E-02	2.1E-01	3					
Famphur	5.81E-05	4.2E+02	1.0E+00	1.0E+00	1.0E+00	0.0E+00	2.1E-01	0.0E+00	1.4E-01	3.2E-01	3					

Table B-2. (continued)

Constituent	Design Inventory (C <sub>D</sub> ) (pCi/kg or mg/kg)	Organic Carbon Partition Coefficient (K <sub>oc</sub> ) (mL/g)	Waste Soils K <sub>d</sub> (mL/g)	Operations Layer K <sub>d</sub> (mL/g)	Clean Alluvium K <sub>d</sub> (mL/g)	Clay Materials K <sub>d</sub> (mL/g)	Interbeds Materials K <sub>d</sub> (mL/g)	Vadose Zone Basalt K <sub>d</sub> (mL/g)	Vadose Zone Weighted Average K <sub>d</sub> (mL/g)	Half-Life (yr)	Surrogates
Fluoranthene	7.62E-01	1.1E+05	2.7E+02	2.7E+02	0.0E+00	5.4E+01	3.6E+01	0.0E+00	1.6E+00	7	
Fluorene	1.84E-01	1.4E+04	3.5E+01	3.5E+01	0.0E+00	6.9E+00	0.0E+00	2.5E-01	2.5E-01	6	
Heptadecane, 2,6,10,15-Tetra	3.44E-03	NA	NA	NA	0.0E+00	NA	NA	NA	NA	1	
Hexachlorobenzene	1.14E-02	5.5E+04	1.4E+02	1.4E+02	0.0E+00	2.8E+01	1.8E+01	0.0E+00	8.4E+00	6	
Hexachlorobutadiene	2.07E-02	5.4E+04	1.3E+02	1.3E+02	0.0E+00	2.7E+01	1.8E+01	0.0E+00	5.3E-01	6	
Hexachlorocyclopentadiene	1.14E-02	2.0E+05	5.0E+02	5.0E+02	0.0E+00	1.0E+02	6.7E+01	0.0E+00	3.3E-01	7	
Hexachloroethane	1.14E-02	1.8E+03	4.5E+00	4.5E+00	0.0E+00	8.9E-01	5.9E-01	0.0E+00	2.9E-01	3	
Indeno(1,2,3-ed)pyrene	1.14E-02	3.5E+06	8.7E+03	8.7E+03	0.0E+00	1.7E+03	1.2E+03	0.0E+00	1.2E+03	8	
Isobutyl alcohol	1.88E-05	4.7E+00	1.2E-02	1.2E-02	0.0E+00	2.4E-03	1.6E-03	0.0E+00	1.2E-02	1	
Isophorone	1.14E-02	4.7E+01	1.2E-01	1.2E-01	0.0E+00	2.3E-02	1.6E-02	0.0E+00	5.8E-01	2	
Isopropyl Alcohol/2-propanol	2.12E-03	8.9E-01	2.2E-03	2.2E-03	0.0E+00	4.5E-04	3.0E-04	0.0E+00	1.1E-02	1	
Kepone	9.92E-02	5.5E+04	1.4E+02	1.4E+02	0.0E+00	2.8E+01	1.8E+01	0.0E+00	1.4E+00	6	
Mesityl oxide	8.48E-02	1.3E+02	3.4E-01	3.4E-01	0.0E+00	6.7E-02	4.5E-02	0.0E+00	3.8E-02	2	
Methyl Acetate	4.84E-04	2.2E+00	5.5E-03	5.5E-03	0.0E+00	7.3E-04	NA	0.0E+00	NA	1	
Methylene Chloride	8.36E-02	1.0E+01	2.5E-02	2.5E-02	0.0E+00	5.0E-03	3.0E-02	0.0E+00	3.0E-02	1	
Naphthalene	4.25E-01	2.0E+03	5.0E+00	5.0E+00	0.0E+00	1.0E+00	6.7E-01	0.0E+00	9.8E-02	3	
Nitrobenzene	1.14E-02	6.5E+01	1.6E-01	1.6E-01	0.0E+00	3.2E-02	2.2E-02	0.0E+00	5.4E-01	2	
N-Nitroso-di-n-propylamine	1.14E-02	2.4E+01	6.0E-02	6.0E-02	0.0E+00	1.2E-02	5.6E-01	0.0E+00	8.0E-03	2	
N-Nitrosodiphenylamine	1.14E-02	1.3E+03	3.2E+00	3.2E+00	0.0E+00	6.5E-01	4.3E-01	0.0E+00	1.2E-01	3	
Octane,2,3,7-Trimethyl	1.61E-04	NA	NA	NA	0.0E+00	NA	NA	0.0E+00	NA	1	
o-Toluenesulfonamide	5.06E-03	NA	NA	NA	0.0E+00	NA	NA	0.0E+00	NA	1	
Pentachlorophenol	5.59E-02	5.9E+00	1.5E+00	1.5E+00	0.0E+00	3.0E-01	2.0E-01	0.0E+00	1.1E+00	3	
Phenanthrene	1.17E+00	4.8E+03	1.2E+01	1.2E+01	0.0E+00	2.4E+00	1.6E+00	0.0E+00	5.9E-01	3	
Phenol	7.98E-02	2.9E+01	7.2E-02	7.2E-02	0.0E+00	1.4E-02	9.6E-03	0.0E+00	1.0E-02	2	
Phenol,2,6-Bis(1,1-Dimethyl)	4.05E-03	2.1E+02	5.2E-01	5.2E-01	0.0E+00	1.0E-01	7.0E-02	0.0E+00	2.2E-02	3	
p-Toluenesulfonamide	5.06E-03	NA	NA	NA	0.0E+00	NA	NA	0.0E+00	NA	1	
Pyrene	2.53E-01	1.1E+05	2.6E+02	2.6E+02	0.0E+00	5.3E+01	3.5E+01	0.0E+00	3.5E+01	7	
RDX	0.00E+00	7.2E+00	1.8E-02	1.8E-02	0.0E+00	3.6E-03	2.4E-03	0.0E+00	NA	1	
Styrene	1.03E-06	9.1E+02	2.3E+00	2.3E+00	0.0E+00	4.6E-01	3.0E-01	0.0E+00	3.1E-01	3	
Tetrachloroethene	9.64E-03	2.7E+02	6.6E-01	6.6E-01	0.0E+00	1.3E-01	8.8E-02	0.0E+00	7.6E-01	3	
Toluene	9.82E-01	1.4E+02	3.5E-01	3.5E-01	0.0E+00	7.0E-02	5.0E-04	0.0E+00	4.7E-02	2	
Trityl phosphate	3.64E-01	NA	NA	NA	0.0E+00	NA	NA	0.0E+00	NA	1	
Trichloroethene	7.20E-02	9.4E+01	2.4E-01	2.4E-01	0.0E+00	4.7E-02	4.7E-02	0.0E+00	3.1E-02	2	
Trinitrotoluene	0.00E+00	1.0E+00	2.5E-03	2.5E-03	0.0E+00	5.0E-04	3.3E-04	0.0E+00	2.8E-01	1	
Undecane,4,6-Dimethyl-	1.61E-04	NA	NA	NA	0.0E+00	NA	NA	0.0E+00	NA	1	
Xylene (ortho)	3.88E-03	2.0E+02	4.9E-01	4.9E-01	0.0E+00	9.8E-02	6.5E-02	0.0E+00	6.5E-02	3	
Xylene (total)	3.45E+00	2.0E+02	4.9E-01	4.9E-01	0.0E+00	9.8E-02	6.5E-02	0.0E+00	7.1E-02	3	
Aluminum	7.08E+03	NA	2.5E+02	2.5E+02	0.0E+00	6.7E+01	NA	0.0E+00	NA	7	
Antimony	5.83E+00	NA	5.0E+01	5.0E+01	0.0E+00	1.5E+01	NA	0.0E+00	NA	6	
Arsenic	5.65E+00	NA	3.0E+00	3.0E+00	0.0E+00	8.3E-01	NA	0.0E+00	NA	3	
Barium	1.79E+02	NA	5.0E+01	5.0E+01	0.0E+00	1.3E+01	NA	0.0E+00	NA	6	
Beryllium	2.87E-01	2.5E+02	1.3E+01	1.3E+01	0.0E+00	7.3E+00	NA	0.0E+00	NA	7	

Table B-2. (continued)

Constituent	Organic Carbon			Operations Layer K <sub>d</sub> (mL/g)	Clean Alluvium K <sub>d</sub> (mL/g)	Clay Materials K <sub>d</sub> (mL/g)	Interbeds Materials K <sub>d</sub> (mL/g)	Vadose Zone Basalt K <sub>d</sub> (mL/g)	Vadose Zone Weighted Average K <sub>d</sub> (mL/g)	Half-Life (yr)	Surrogates
	Design Inventory (C <sub>Dl</sub> ) (pCi/kg or mg/kg)	Partition Coefficient (K <sub>oc</sub> ) (mL/g)	Waste Soils K <sub>d</sub> (mL/g)								
Boron	1.85E+02	NA	5.0E+00	5.0E+00	5.0E+00	1.0E+00	5.0E+00	0.0E+00	1.3E+00	NA	3
Cadmium	3.59E+00	NA	6.0E+00	6.0E+00	5.6E+02	6.0E+00	0.0E+00	0.0E+00	4.9E+00	NA	6
Calcium	2.04E+04	NA	5.0E+00	5.0E+00	5.0E+00	5.0E+01	5.0E+00	0.0E+00	1.6E+00	NA	3
Chloride	1.87E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	NA	1
Chromium	4.12E+01	NA	3.0E+01	3.0E+01	3.0E+01	1.5E+03	3.0E+01	0.0E+00	1.7E+01	NA	6
Cobalt	6.04E+00	NA	1.0E+01	1.0E+01	1.0E+01	5.5E+02	1.0E+01	0.0E+00	5.9E+00	NA	6
Copper	2.99E+01	NA	2.0E+01	2.0E+01	2.0E+01	2.0E+01	2.0E+01	2.0E+01	5.4E+00	NA	6
Cyanide	3.37E-01	8.9E+00	2.2E-02	2.2E-02	2.2E-02	0.0E+00	0.0E+00	0.0E+00	3.0E-03	NA	1
Dysprosium	5.93E+01	NA	2.4E+02	2.4E+02	2.4E+02	2.4E+02	2.4E+02	0.0E+00	6.4E+01	NA	7
Fluoride	3.87E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	NA	1
Iron	1.02E+04	NA	2.2E+02	2.2E+02	2.2E+02	1.7E+02	2.2E+02	2.2E+02	2.2E+02	NA	7
Lead	5.76E+01	NA	1.0E+02	1.0E+02	1.0E+02	7.1E+02	1.0E+02	1.0E+02	1.0E+02	NA	7
Magnesium	4.47E+03	NA	5.0E+00	5.0E+00	5.0E+00	5.0E+01	5.0E+00	5.0E+00	5.0E+00	NA	3
Manganese	2.07E+02	NA	5.0E+01	5.0E+01	5.0E+01	1.8E+02	5.0E+01	5.0E+01	5.9E+01	NA	6
Mercury	9.45E+00	5.2E+01	1.3E-01	1.3E-01	1.3E-01	0.0E+00	0.0E+00	0.0E+00	2.6E-02	NA	5
Molybdenum	1.02E+01	NA	1.0E+01	1.0E+01	1.0E+01	9.0E+01	1.0E+01	1.0E+01	1.6E+00	NA	5
Nickel	1.97E+01	NA	1.0E+02	1.0E+02	1.0E+02	6.5E+02	1.0E+02	1.0E+02	1.4E+01	NA	7
Nitrate	3.93E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.7E-02	NA	1
Nitrate/Nitrite-N	2.22E-01	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.2E+00	NA	1
Nitrite	8.49E-03	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.0E+01	NA	1
Phosphorus	9.74E+01	NA	5.0E+00	5.0E+00	5.0E+00	3.5E+01	5.0E+00	5.0E+00	1.5E+00	NA	3
Potassium	1.13E+03	NA	1.5E+01	1.5E+01	1.5E+01	7.5E+01	1.5E+01	1.5E+01	4.4E+00	NA	5
Selenium	8.46E-01	NA	4.0E+00	4.0E+00	4.0E+00	4.0E+00	4.0E+00	4.0E+00	5.5E+00	NA	6
Silver	9.84E+00	NA	9.0E+01	9.0E+01	9.0E+01	1.8E+02	9.0E+01	9.0E+01	2.5E+01	NA	7
Sodium	2.11E+02	NA	7.6E+01	7.6E+01	7.6E+01	7.6E+01	7.6E+01	7.6E+01	2.0E+01	NA	7
Strontrium	1.82E+01	NA	1.2E+01	1.2E+01	1.2E+01	2.4E+01	1.2E+01	2.4E+01	1.2E+01	NA	6
Sulfate	2.05E+01	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	NA	1
Sulfide	7.59E+02	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	NA	1
Terbium	5.73E+02	NA	2.4E+02	2.4E+02	2.4E+02	2.4E+02	2.4E+02	2.4E+02	2.4E+02	NA	7
Thallium	3.70E-01	NA	1.0E+02	1.0E+02	1.0E+02	1.0E+02	1.0E+02	1.0E+02	2.7E+01	NA	7
Vandium	2.12E+01	NA	6.0E+00	6.0E+00	6.0E+00	6.0E+00	6.0E+00	6.0E+00	1.6E+00	NA	3
Ytterbium	1.95E+02	NA	2.4E+02	2.4E+02	2.4E+02	2.4E+02	2.4E+02	2.4E+02	6.4E+01	NA	7
Zinc	2.08E+02	NA	1.6E+01	1.6E+01	1.6E+01	2.4E+03	1.6E+01	1.6E+01	1.9E+01	NA	7
Zirconium	6.91E+01	NA	6.0E+02	6.0E+02	6.0E+02	3.3E+03	6.0E+02	6.0E+02	1.8E+02	NA	8

NA= Not available

Table B-3. Summary of maximum concentrations over time ( $C_T$ ).

Constituent	Maximum Concentration pCi/L or mg/L
Ac225	0.00E+00
Ac227	0.00E+00
Ac228	0.00E+00
Ag106	0.00E+00
Ag108	0.00E+00
Ag108m	1.08E-147
Ag109m	0.00E+00
Ag110	0.00E+00
Ag110m	0.00E+00
Ag111	0.00E+00
Am241	0.00E+00
Am242	0.00E+00
Am242m	0.00E+00
Am243	8.96E-43
Am245	0.00E+00
Am246	0.00E+00
At217	0.00E+00
Ba136m	0.00E+00
Ba137m	0.00E+00
Ba140	0.00E+00
Be 10	3.53E-11
Bi210	0.00E+00
Bi211	0.00E+00
Bi212	0.00E+00
Bi213	0.00E+00
Bi214	0.00E+00
Bk249	0.00E+00
Bk250	0.00E+00
C 14	4.63E-08
Cd109	0.00E+00
Cd113m	0.00E+00
Cd115m	0.00E+00
Ce141	0.00E+00
Ce142	0.00E+00
Ce144	0.00E+00
Cf249	0.00E+00
Cf250	0.00E+00
Cf251	4.10E-214
Cf252	0.00E+00
Cm241	0.00E+00
Cm242	0.00E+00
Cm243	0.00E+00
Cm244	0.00E+00
Cm245	1.57E-43
Cm246	3.25E-60
Cm247	3.17E-29
Cm248	1.31E-30

Table B-3. (continued).

Constituent	Maximum Concentration pCi/L or mg/L
Cm250	2.33E-58
Co-57	0.00E+00
Co-58	0.00E+00
Co-60	0.00E+00
Cr-51	0.00E+00
Cs132	0.00E+00
Cs134	0.00E+00
Cs135	1.37E-15
Cs136	0.00E+00
Cs137	0.00E+00
Er169	0.00E+00
Eu150	0.00E+00
Eu152	0.00E+00
Eu154	0.00E+00
Eu155	0.00E+00
Eu156	0.00E+00
Fe-59	0.00E+00
Fr221	0.00E+00
Fr223	0.00E+00
Gd152	1.33E-18
Gd153	0.00E+00
H 3	2.15E-08
Hf-181	0.00E+00
Ho166m	0.00E+00
I129	1.28E-01
I131	0.00E+00
In114	0.00E+00
In114m	0.00E+00
In115	3.00E-25
In115m	0.00E+00
K-40	5.69E-03
Kr81	5.75E-10
Kr85	2.27E-07
La138	0.00E+00
La140	0.00E+00
Mn-54	0.00E+00
Nb92	3.04E-23
Nb93m	0.00E+00
Nb94	1.10E-16
Nb95	0.00E+00
Nb95m	0.00E+00
Nd144	1.59E-14
Nd147	0.00E+00
Np235	0.00E+00
Np236	4.30E-12
Np237	1.38E-03
Np238	0.00E+00
Np239	0.00E+00
Np240	0.00E+00

Table B-3. (continued).

Constituent	Maximum Concentration pCi/L or mg/L
Np240m	0.00E+00
Pa231	1.89E-26
Pa233	0.00E+00
Pa234	0.00E+00
Pa234m	0.00E+00
Pb209	0.00E+00
Pb210	0.00E+00
Pb211	0.00E+00
Pb212	0.00E+00
Pb214	0.00E+00
Pd107	4.54E-06
Pm146	0.00E+00
Pm147	0.00E+00
Pm148	0.00E+00
Pm148m	0.00E+00
Po210	0.00E+00
Po211	0.00E+00
Po212	0.00E+00
Po213	0.00E+00
Po214	0.00E+00
Po215	0.00E+00
Po216	0.00E+00
Po218	0.00E+00
Pr143	0.00E+00
Pr144	0.00E+00
Pr144m	0.00E+00
Pu236	0.00E+00
Pu237	0.00E+00
Pu238	1.05E-204
Pu239	2.90E-10
Pu240	2.81E-16
Pu241	0.00E+00
Pu242	1.86E-09
Pu243	0.00E+00
Pu244	1.23E-15
Pu246	0.00E+00
Ra222	0.00E+00
Ra223	0.00E+00
Ra224	0.00E+00
Ra225	0.00E+00
Ra226	1.00E-25
Ra228	0.00E+00
Rb86	0.00E+00
Rb87	9.21E-09
Rh102	0.00E+00
Rh103m	0.00E+00
Rh106	0.00E+00
Rn218	0.00E+00
Rn219	0.00E+00

Table B-3. (continued).

Constituent	Maximum Concentration pCi/L or mg/L
Rn220	0.00E+00
Rn222	0.00E+00
Ru103	0.00E+00
Ru106	0.00E+00
Sb124	0.00E+00
Sb125	0.00E+00
Sb126	0.00E+00
Sb126m	0.00E+00
Sc-46	0.00E+00
Se 79	1.30E-07
Sm146	2.06E-14
Sm147	2.00E-10
Sm148	4.92E-17
Sm149	2.50E-16
Sm151	1.24E-199
Sn117m	0.00E+00
Sn119m	0.00E+00
Sn121m	0.00E+00
Sn123	0.00E+00
Sn125	0.00E+00
Sn126	1.79E-08
Sr89	0.00E+00
Sr90	0.00E+00
Tb160	0.00E+00
Tb161	0.00E+00
Tc 98	1.11E-08
Tc 99	3.04E-01
Te123	2.20E-19
Te123m	0.00E+00
Te125m	0.00E+00
Te127	0.00E+00
Te127m	0.00E+00
Te129	0.00E+00
Te129m	0.00E+00
Th226	0.00E+00
Th227	0.00E+00
Th228	0.00E+00
Th229	3.77E-23
Th230	6.56E-09
Th231	0.00E+00
Th232	7.60E-06
Th234	0.00E+00
Tl207	0.00E+00
Tl208	0.00E+00
Tl209	0.00E+00
Tm170	0.00E+00
Tm171	0.00E+00
U230	0.00E+00
U232	3.85E-77

Table B-3. (continued).

Constituent	Maximum Concentration pCi/L or mg/L
U233	6.62E-09
U234	3.26E-03
U235	3.78E-04
U236	6.76E-04
U237	0.00E+00
U238	6.69E-03
U240	0.00E+00
Xe127	1.75E-161
Xe129m	0.00E+00
Xe131m	0.00E+00
Xe133	0.00E+00
Y90	0.00E+00
Y91	0.00E+00
Zn65	0.00E+00
Zr93	2.82E-14
Zr95	0.00E+00
1,1,1-Trichloroethane	4.3E-27
1,1,2,2-Tetrachloroethane	7.07E-75
1,1,2-Trichloroethane	4.6E-27
1,1-Dichloroethane	1.2E-33
1,1-Dichloroethene	1.57E-50
1,2,4-Trichlorobenzene	4.93E-49
1,2-Dichlorobenzene	0.00E+00
1,2-Dichloroethane	9.24E-35
1,2-Dichloroethene (total)	1.62E-27
1,3-Dichlorobenzene	4.93E-49
1,4-Dichlorobenzene	1.95E-47
1,4-Dioxane	1.7E-33
2,4,5-Trichlorophenol	7.7E-25
2,4,6-Trichlorophenol	2.49E-25
2,4-Dichlorophenol	4.1E-143
2,4-Dimethylphenol	0.00E+00
2,4-Dinitrophenol	3.5E-27
2,4-Dinitrotoluene	6.40E-35
2,6-Dinitrotoluene	1.16E-34
2-Butanone	1.7E-27
2-Chloronaphthalene	1.57E-111
2-Chlorophenol	4.1E-39
2-Hexanone	3.23E-07
2-Methylnaphthalene	3.24E-05
2-Methylphenol	7.76E-235
2-Nitroaniline	3.26E-06
2-Nitrophenol	1.18E-162
3,3'-Dichlorobenzidine	2.1E-49
3-Methyl Butanal	2.68E-08
3-Nitroaniline	3.26E-06
4,6-Dinitro-2-methylphenol	1.23E-174
4-Bromophenyl-phenylether	9.40E-09
4-Chloro-3-methylphenol	1.81E-06

Table B-3. (continued).

Constituent	Maximum Concentration pCi/L or mg/L
4-Chloroaniline	4.04E-06
4-Chlorophenyl-phenylether	7.20E-07
4-Methyl-2-Pentanone	1.12E-234
4-Methylphenol	1.45E-234
4-Nitroaniline	3.26E-06
4-Nitrophenol	0.00E+00
Acenaphthene	0.00E+00
Acenaphthylene	6.95E-81
Acetone	0.0E+00
Acetonitrile	5.0E-35
Acrolein	3.6E-108
Acrylonitrile	1.54E-136
Anthracene	0.00E+00
Aramite	9.46E-11
Aroclor-1016	0.0E+00
Aroclor-1254	0.0E+00
Aroclor-1260	0.0E+00
Aroclor-1268	0.0E+00
Benzene	5.7E-25
Benzidine	0.00E+00
Benzo(a)anthracene	0.00E+00
Benzo(a)pyrene	0.00E+00
Benzo(b)fluoranthene	0.00E+00
Benzo(g,h,i)perylene	0.00E+00
Benzo(k)fluoranthene	0.00E+00
Benzoic acid	0.00E+00
bis(2-Chloroethoxy)methane	1.36E-06
bis(2-Chloroethyl)ether	8.46E-33
bis(2-Chloroisopropyl)ether	1.0E-33
bis(2-Ethylhexyl)phthalate	0.00E+00
Butane,1,1,3,4-Tetrachloro-	1.13E-72
Butylbenzylphthalate	0.00E+00
Carbazole	2.05E-06
Carbon Disulfide	0.00E+00
Chlorobenzene	3.2E-48
Chloroethane	0.0E+00
Chloromethane	3.50E-08
Chrysene	0.00E+00
Decane, 3,4-Dimethyl	1.94E-08
Diacetone alcohol	1.63E-232
Dibenz(a,h)anthracene	0.00E+00
Dibenzofuran	0.0E+00
Diethylphthalate	2.75E-127
Dimethyl Disulfide	3.55E-07
Dimethylphthalate	0.00E+00
Di-n-butylphthalate	0.00E+00
Di-n-octylphthalate	0.00E+00
Eicosane	0.00E+00
Ethyl cyanide	2.26E-09

Table B-3. (continued).

Constituent	Maximum Concentration pCi/L or mg/L
Ethylbenzene	1.5E-72
Famphur	1.24E-76
Fluoranthene	0.00E+00
Fluorene	0.00E+00
Heptadecane, 2,6,10,15-Tetra	4.12E-07
Hexachlorobenzene	0.00E+00
Hexachlorobutadiene	0.0E+00
Hexachlorocyclopentadiene	0.0E+00
Hexachloroethane	2.1E-49
Indeno(1,2,3-cd)pyrene	0.0E+00
Isobutyl alcohol	0.0E+00
Isophorone	4.5E-105
Isopropyl Alcohol/2-propanol	0.0E+00
Kepone	0.0E+00
Mesityl oxide	3.19E-234
Methyl Acetate	5.81E-08
Methylene Chloride	0.0E+00
Naphthalene	1.6E-66
Nitrobenzene	1.06E-33
N-Nitroso-di-n-propylamine	2.70E-33
N-Nitrosodiphenylamine	2.35E-164
Octane,2,3,7-Trimethyl	1.94E-08
o-Toluenesulfonamide	6.07E-07
Pentachlorophenol	4.6E-26
Phenanthrene	3.83E-46
Phenol	0.00E+00
Phenol,2,6-Bis(1,1-Dimethyl)	0.00E+00
p-Toluenesulfonamide	6.07E-07
Pyrene	0.00E+00
RDX	0.00E+00
Styrene	1.01E-79
Tetrachloroethene	1.6E-30
Toluene	8.1E-190
Tributylphosphate	4.36E-05
Trichloroethene	1.8E-20
Trinitrotoluene	0.0E+00
Undecane,4,6-Dimethyl-	1.94E-08
Xylene (ortho)	2.5E-53
Xylene (total)	2.2E-50
Aluminum	3.45E-04
Antimony	4.82E-06
Arsenic	3.57E-04
Barium	1.48E-04
Beryllium	1.40E-08
Boron	1.17E-02
Cadmium	2.96E-06
Calcium	1.29E+00
Chloride	2.24E-04
Chromium	3.40E-05

Table B-3. (continued).

Constituent	Maximum Concentration pCi/L or mg/L
Cobalt	4.99E-06
Copper	2.47E-05
Cyanide	4.04E-05
Dysprosium	2.89E-06
Fluoride	4.64E-04
Iron	4.99E-04
Lead	2.81E-06
Magnesium	2.83E-01
Manganese	1.71E-04
Mercury	4.61E-07
Molybdenum	3.02E-05
Nickel	9.58E-07
Nitrate	4.71E-04
Nitrate/Nitrite-N	2.66E-05
Nitrite	1.02E-06
Phosphorus	6.16E-03
Potassium	3.35E-03
Selenium	6.99E-07
Silver	4.80E-07
Sodium	1.03E-05
Strontium	1.50E-05
Sulfate	2.46E-03
Sulfide	9.10E-02
Terbium	2.79E-05
Thallium	1.81E-08
Vanadium	1.34E-03
Ytterbium	4.63E-13
Zinc	1.01E-05
Zirconium	3.58E-15

Table B-4. Summary of input parameters for RAO calculations.

Constituent	Individual Concentration (RBC) (mg/L or pCi/L)			Risk Factor (mg/L or pCi/L)			Individual MCL			Beta & Photon Emitters MCL C4 Values		
	Carcinogenic	Non-Carcinogenic	Carcinogenic	Non-Carcinogenic	Carcinogenic	pCi/L or mg/L	Total Body GI(LL)	GI(S)	Liver	Fat	Thyroid	Pancreas
							(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)
Ac225	2.79E+01	—	—	2.79E+05	No Limit	—	—	—	—	—	—	—
Ac227	2.63E+01	—	—	2.63E+05	No Limit	—	—	—	—	—	—	Yes
Ac228	2.65E+03	—	—	2.65E+07	No Limit	—	—	—	—	—	—	—
Ag106	8.93E+04	—	—	8.93E+08	No Limit	—	—	—	—	—	—	—
Ag108	—	—	—	No Limit	No Limit	—	—	—	—	—	—	—
Ag108m	6.49E+02	—	—	6.49E+06	No Limit	—	—	—	—	—	—	—
Ag109m	—	—	—	No Limit	No Limit	—	—	—	—	—	—	—
Ag110	—	—	—	No Limit	No Limit	—	—	—	—	—	—	—
Ag110m	5.35E+02	—	—	5.35E+06	No Limit	—	—	—	—	—	—	90
Ag111	6.44E+02	—	—	6.44E+06	No Limit	—	—	—	—	—	—	100
Am241	5.08E+01	—	—	5.08E+05	No Limit	—	—	—	—	—	—	—
Am242	2.95E+03	—	—	2.95E+07	No Limit	—	—	—	—	—	—	—
Am242m	7.47E+01	—	—	7.47E+05	No Limit	—	—	—	—	—	—	—
Am243	5.13E+01	—	—	5.13E+05	No Limit	—	—	—	—	—	—	—
Am245	2.38E+04	—	—	2.38E+08	No Limit	—	—	—	—	—	—	—
Am246	4.29E+04	—	—	4.29E+08	No Limit	—	—	—	—	—	—	—
At217	—	—	—	No Limit	No Limit	—	—	—	—	—	—	—
Ba136m	—	—	—	No Limit	No Limit	—	—	—	—	—	—	—
Ba137m	—	—	—	No Limit	No Limit	—	—	—	—	—	—	—
Ba140	3.54E+02	—	—	3.54E+06	No Limit	—	—	—	—	—	—	—
Be10	7.51E+02	—	—	7.51E+06	No Limit	—	—	—	—	—	—	—
Bi210	5.92E+02	—	—	5.92E+06	No Limit	—	—	—	—	—	—	—
Bi211	—	—	—	No Limit	No Limit	—	—	—	—	—	—	—
Bi212	7.44E+03	—	—	7.44E+07	No Limit	—	—	—	—	—	—	—
Bi213	1.03E+04	—	—	1.03E+08	No Limit	—	—	—	—	—	—	—
Bi214	2.75E+04	—	—	2.75E+08	No Limit	—	—	—	—	—	—	—
Bk249	4.76E+03	—	—	4.76E+07	No Limit	—	—	—	—	—	—	—
Bk250	9.33E+03	—	—	9.33E+07	No Limit	—	—	—	—	—	—	—
C14	3.41E+03	—	—	3.41E+07	No Limit	—	—	—	—	—	—	—
Cd109	1.06E+03	—	—	1.06E+07	No Limit	—	—	—	—	—	—	600
Cd113m	1.84E+02	—	—	1.84E+06	No Limit	—	—	—	—	—	—	—
Cd115m	3.11E+02	—	—	3.11E+06	No Limit	—	—	—	—	—	—	90
Ce141	1.14E+03	—	—	1.14E+07	No Limit	—	—	—	—	—	—	300
Ce142	—	—	—	No Limit	No Limit	—	—	—	—	—	—	—
Ce144	1.50E+02	—	—	1.50E+06	No Limit	—	—	—	—	—	—	—
Cf249	4.16E+01	—	—	4.16E+05	No Limit	—	—	—	—	—	—	—
Cf250	6.13E+01	—	—	6.13E+05	No Limit	—	—	—	—	—	—	—
Cf251	4.00E+01	—	—	4.00E+05	No Limit	—	—	—	—	—	—	—
Cf252	—	—	—	No Limit	No Limit	—	—	—	—	—	—	—
Cm241	1.09E+03	—	—	1.09E+07	No Limit	—	—	—	—	—	—	—

Table B-4. (continued).

Constituent	Individual Concentration (RBC) (mg/L or pCi/L)			Risk Factor (mg/L or pCi/L)			Individual MCL			Beta & Photon Emitters MCL C4 Values		
	Carcinogenic	Non-Carcinogenic	Carcinogenic	Carcinogenic	Non-Carcinogenic	Carcinogenic	Total Body	GI(LL)	GI(S)	Liver	Fat	Bone
							(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	Marrow (FRC)
Cm242	1.37E+02	—	—	1.37E+06	No Limit	—	—	—	—	—	—	Yes
Cm243	5.58E+01	—	—	5.58E+05	No Limit	—	—	—	—	—	—	Yes
Cm244	6.32E+01	—	—	6.32E+05	No Limit	—	—	—	—	—	—	Yes
Cm245	5.08E+01	—	—	5.08E+05	No Limit	—	—	—	—	—	—	Yes
Cm246	5.18E+01	—	—	5.18E+05	No Limit	—	—	—	—	—	—	Yes
Cm247	5.31E+01	—	—	5.31E+05	No Limit	—	—	—	—	—	—	Yes
Cm248	—	—	—	—	No Limit	No Limit	—	—	—	—	—	Yes
Cm250	—	—	—	—	No Limit	No Limit	—	—	—	—	—	Yes
Co-57	5.08E+03	—	—	5.08E+07	No Limit	—	—	—	—	1000	—	—
Co-58	1.79E+03	—	—	1.79E+07	No Limit	—	—	—	—	9000	—	—
Co-60	3.37E+02	—	—	3.37E+06	No Limit	—	—	—	—	100	—	—
Cr-51	2.85E+04	—	—	2.85E+08	No Limit	—	—	—	—	—	—	—
Cs132	3.62E+03	—	—	3.62E+07	No Limit	—	—	—	—	—	—	—
Cs134	1.25E+02	—	—	1.25E+06	No Limit	—	—	—	—	—	—	—
Cs135	1.11E+03	—	—	1.11E+07	No Limit	—	—	—	—	900	—	—
Cs136	6.10E+02	—	—	6.10E+06	No Limit	—	—	—	—	800	—	—
Cs137	1.74E+02	—	—	1.74E+06	No Limit	—	—	—	—	200	—	—
Er169	2.09E+03	—	—	2.09E+07	No Limit	—	—	—	—	300	—	—
Eu150	2.22E+03	—	—	2.22E+07	No Limit	—	—	—	—	—	—	—
Eu152	8.70E+02	—	—	8.70E+06	No Limit	—	—	—	—	60	—	—
Eu154	5.13E+02	—	—	5.13E+06	No Limit	—	—	—	—	200	—	—
Eu155	2.78E+03	—	—	2.78E+07	No Limit	—	—	—	—	600	—	—
Eu156	4.16E+02	—	—	4.16E+06	No Limit	—	—	—	—	200	—	—
Fe-59	6.70E+02	—	—	6.70E+06	No Limit	—	—	—	—	—	—	—
Fr221	—	—	—	—	No Limit	No Limit	—	—	—	—	—	—
Fr223	7.24E+02	—	—	7.24E+06	No Limit	—	—	—	—	—	—	—
Gd152	1.78E+02	—	—	1.78E+06	No Limit	—	—	—	—	—	—	—
Gd153	3.47E+03	—	—	3.47E+07	No Limit	—	—	—	—	600	—	—
H-3	1.04E+05	—	—	1.04E+09	No Limit	—	—	—	—	200000	—	—
Hf-181	8.30E+02	—	—	8.30E+06	No Limit	—	—	—	—	200	—	—
Ho166m	5.73E+02	—	—	5.73E+06	No Limit	—	—	—	—	—	—	—
I-129	3.57E+01	—	—	3.57E+05	No Limit	—	—	—	—	—	—	—
I-131	1.16E+02	—	—	1.16E+06	No Limit	—	—	—	—	—	—	—
In114	—	—	—	—	No Limit	No Limit	—	—	—	—	—	—
In114m	2.13E+02	—	—	2.13E+06	No Limit	—	—	—	—	60	—	—
In115	1.56E+02	—	—	1.56E+06	No Limit	—	—	—	—	300	—	—
In115m	1.20E+04	—	—	1.20E+08	No Limit	—	—	—	—	1000	—	—
K-40	2.14E+02	—	—	2.14E+06	No Limit	—	—	—	—	—	—	—
Kr81	—	—	—	—	No Limit	No Limit	—	—	—	—	—	—
Kr85	—	—	—	—	No Limit	No Limit	—	—	—	—	—	—

Table B-4. (continued).

Constituent	Individual Concentration (RBC) (mg/L or pCi/L)		Risk Factor (mg/L or pCi/L)		Individual MCL		Beta & Photon Emitters MCL C4 Values										
	Carcinogenic	Non-Carcinogenic	Carcinogenic	Non-Carcinogenic	Total Body	GI(LLI)	GI(S)	Liver									
					pCi/L or mg/L	(pCi/L)	(pCi/L)	(pCi/L)	Bone Marrow (FRC)	Kidney (pCi/L)	Bone (FRC)	Pancreas (pCi/L)	Thyroid (pCi/L)	Fat (pCi/L)	Bone Marrow (FRC)	Kidney (pCi/L)	MCL Alpha emitter?
La138	1.50E+03	—	—	1.50E+07	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
La140	4.80E+02	—	—	4.80E+06	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Mn-54	2.32E+03	—	—	2.32E+07	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Nb92	—	—	—	No Limit	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Nb93m	6.80E+02	—	—	6.80E+06	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Nb94	—	—	—	No Limit	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Nb95	2.16E+03	—	—	2.16E+07	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Nb95m	1.44E+03	—	—	1.44E+07	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Nd144	—	—	—	No Limit	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Nd147	7.59E+02	—	—	7.59E+06	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Np235	1.53E+04	—	—	1.53E+08	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Np236	5.03E+02	—	—	5.03E+06	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Np237	8.54E+01	—	—	8.54E+05	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Np238	9.78E+02	—	—	9.78E+06	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Np239	1.03E+03	—	—	1.03E+07	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Np240	2.37E+04	—	—	2.37E+08	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Np240m	—	—	—	No Limit	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Pa231	3.05E+01	—	—	3.05E+05	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Pa233	9.51E+02	—	—	9.51E+06	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Pa234	2.06E+03	—	—	2.06E+07	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Pa234m	—	—	—	No Limit	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Pb209	2.19E+04	—	—	2.19E+08	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Pb210	6.00E+00	—	—	6.00E+04	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Pb211	1.29E+04	—	—	1.29E+08	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Pb212	2.12E+02	—	—	2.12E+06	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Pb214	1.54E+04	—	—	1.54E+08	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Pd107	2.11E+04	—	—	2.11E+08	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Pm146	1.26E+03	—	—	1.26E+07	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Pm147	3.12E+03	—	—	3.12E+07	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Pm148	3.07E+02	—	—	3.07E+06	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Pm148m	6.61E+02	—	—	6.61E+06	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Po210	1.40E+01	—	—	1.40E+05	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Po211	—	—	—	No Limit	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Po212	—	—	—	No Limit	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Po213	—	—	—	No Limit	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Po214	—	—	—	No Limit	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Po215	—	—	—	No Limit	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Po216	—	—	—	No Limit	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Po218	—	—	—	No Limit	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	
Pr143	6.67E+02	—	—	6.67E+06	No Limit	60	300	1000	60	300	1000	300	1000	1000	1000	1000	

Table B-4. (continued).

Constituent	Individual Concentration (RBC) (mg/L or pCi/L)			Risk Factor (mg/L or pCi/L)			Individual MCL			Beta & Photon Emitters MCL C4 Values		
	Carcinogenic	Non-Carcinogenic	Carcinogenic	Carcinogenic	Non-Carcinogenic	Carcinogenic	Total Body	GI(LL)	GI(S)	Liver	Fat	Bone
Pr144	6.52E+04	—	—	6.52E+08	No Limit	No Limit	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	Marrow (FRC)
Pr144m	—	—	—	—	No Limit	No Limit	—	—	—	—	—	Yes
Pu236	7.07E+01	—	—	7.07E+05	No Limit	No Limit	—	—	—	—	—	Yes
Pu237	9.15E+03	—	—	9.15E+07	No Limit	No Limit	—	—	—	—	—	Yes
Pu238	4.03E+01	—	—	4.03E+05	No Limit	No Limit	—	—	—	—	—	Yes
Pu239	3.91E+01	—	—	3.91E+05	No Limit	No Limit	—	—	—	—	—	Yes
Pu240	3.91E+01	—	—	3.91E+05	No Limit	No Limit	—	—	—	—	—	Yes
Pu241	3.00E+03	—	—	3.00E+07	No Limit	No Limit	—	—	—	—	—	Yes
Pu242	4.12E+01	—	—	4.12E+05	No Limit	No Limit	—	—	—	—	—	Yes
Pu243	1.11E+04	—	—	1.11E+08	No Limit	No Limit	—	—	—	—	—	Yes
Pu244	3.85E+01	—	—	3.85E+05	No Limit	No Limit	—	—	—	—	—	Yes
Pu246	3.05E+02	—	—	3.05E+06	No Limit	No Limit	—	—	—	—	—	Yes
Ra222	—	—	—	—	No Limit	No Limit	—	—	—	—	—	Yes
Ra223	2.22E+01	—	—	2.22E+05	No Limit	No Limit	—	—	—	—	—	Yes
Ra224	3.16E+01	—	—	3.16E+05	No Limit	No Limit	—	—	—	—	—	Yes
Ra225	4.63E+01	—	—	4.63E+05	No Limit	No Limit	—	—	—	—	—	Yes
Ra226	1.37E+01	—	—	1.37E+05	No Limit	No Limit	—	—	—	—	—	Yes
Ra228	5.08E+00	—	—	<Background	<Background	<Background	—	—	—	—	—	—
Rb86	5.34E+02	—	—	5.34E+06	No Limit	No Limit	—	—	—	—	—	—
Rb87	1.01E+03	—	—	1.01E+07	No Limit	No Limit	—	—	—	—	—	—
Rh102	6.86E+02	—	—	6.86E+06	No Limit	No Limit	—	—	—	—	—	—
Rh103m	5.62E+05	—	—	5.62E+09	No Limit	No Limit	—	—	—	—	—	—
Rh106	—	—	—	—	No Limit	No Limit	—	—	—	—	—	—
Rn218	—	—	—	—	No Limit	No Limit	—	—	—	—	—	—
Rn219	—	—	—	—	No Limit	No Limit	—	—	—	—	—	—
Rn220	—	—	—	—	No Limit	No Limit	—	—	—	—	—	—
Rn222	—	—	—	—	No Limit	No Limit	—	—	—	—	—	—
Ru103	1.37E+03	—	—	1.37E+07	No Limit	No Limit	—	—	—	—	—	Yes
Ru106	1.25E+02	—	—	1.25E+06	No Limit	No Limit	—	—	—	—	—	Yes
Sb124	4.09E+02	—	—	4.09E+06	No Limit	No Limit	—	—	—	—	—	Yes
Sb125	1.21E+03	—	—	1.21E+07	No Limit	No Limit	—	—	—	—	—	Yes
Sb126	4.76E+02	—	—	4.76E+06	No Limit	No Limit	—	—	—	—	—	Yes
Sb126m	7.93E+04	—	—	7.93E+08	No Limit	No Limit	—	—	—	—	—	Yes
Sc46	8.49E+02	—	—	8.49E+06	No Limit	No Limit	—	—	—	—	—	Yes
Se79	7.24E+02	—	—	7.24E+06	No Limit	No Limit	—	—	—	—	—	Yes
Sm146	1.28E+02	—	—	1.28E+06	No Limit	No Limit	—	—	—	—	—	Yes
Sm147	1.41E+02	—	—	1.41E+06	No Limit	No Limit	—	—	—	—	—	Yes
Sm148	—	—	—	—	No Limit	No Limit	—	—	—	—	—	Yes
Sm149	—	—	—	—	No Limit	No Limit	—	—	—	—	—	Yes
Sm151	9.51E+03	—	—	9.51E+07	No Limit	No Limit	—	—	—	—	—	Yes

Table B-4. (continued).

Constituent	Individual Concentration (RBC) (mg/L or pCi/L)			Risk Factor (mg/L or pCi/L)			Individual MCL			Beta & Photon Emitters MCL C4 Values		
	Carcinogenic	Non-Carcinogenic	Carcinogenic	Carcinogenic	Non-Carcinogenic	Carcinogenic	Total Body	GI(LL)	GI(S)	Liver	Fat	Bone
							(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(FRC)
Sn117m	1.21E+03	—	—	1.21E+07	No Limit	2.39E+07	No Limit	2.39E+07	2.26E+07	No Limit	20	80
Sn119m	2.39E+03	—	—	2.39E+07	No Limit	2.26E+07	No Limit	3.77E+02	3.77E+06	No Limit	60	—
Sn121m	2.26E+03	—	—	2.26E+07	No Limit	2.63E+02	No Limit	2.06E+02	2.06E+06	No Limit	—	—
Sn123	3.77E+02	—	—	3.77E+06	No Limit	4.12E+02	No Limit	4.12E+02	4.12E+06	No Limit	—	—
Sn125	2.63E+02	—	—	2.63E+06	No Limit	9.45E+01	No Limit	9.45E+01	9.45E+05	No Limit	—	—
Sn126	2.06E+02	—	—	2.06E+06	No Limit	6.07E+02	No Limit	6.07E+02	6.07E+06	No Limit	100	—
Sr89	4.12E+02	—	—	4.12E+06	No Limit	1.11E+03	No Limit	1.11E+03	1.11E+07	No Limit	—	—
Sr90	9.45E+01	—	—	9.45E+05	No Limit	7.44E+02	No Limit	7.44E+02	7.44E+06	No Limit	—	—
Tb160	6.07E+02	—	—	6.07E+06	No Limit	1.92E+03	No Limit	1.92E+03	1.92E+07	No Limit	—	—
Tb161	1.11E+03	—	—	1.11E+07	No Limit	1.28E+03	No Limit	1.28E+03	1.28E+07	No Limit	—	—
Tc 98	7.44E+02	—	—	7.44E+06	No Limit	1.28E+03	No Limit	1.28E+03	1.28E+07	No Limit	—	—
Tc 99	1.92E+03	—	—	1.92E+07	No Limit	1.59E+03	No Limit	1.59E+03	1.59E+07	No Limit	900	600
Te123	1.28E+03	—	—	1.28E+07	No Limit	6.13E+02	No Limit	6.13E+02	6.13E+06	No Limit	—	200
Te123m	1.28E+03	—	—	1.28E+07	No Limit	3.09E+04	No Limit	3.09E+04	3.09E+08	No Limit	—	900
Te125m	1.59E+03	—	—	1.59E+07	No Limit	3.45E+02	No Limit	3.45E+02	3.45E+06	No Limit	—	—
Te127	5.28E+03	—	—	5.28E+07	No Limit	7.93E+03	No Limit	7.93E+03	7.93E+07	No Limit	—	—
Te127m	6.13E+02	—	—	6.13E+06	No Limit	1.11E+02	No Limit	1.11E+02	1.11E+06	No Limit	—	—
Te129	6.13E+02	—	—	6.13E+06	No Limit	4.93E+01	No Limit	4.93E+01	4.93E+05	No Limit	—	—
Te129m	3.09E+04	—	—	3.09E+08	No Limit	3.45E+02	No Limit	3.45E+02	3.45E+06	No Limit	—	—
Th226	7.93E+03	—	—	7.93E+07	No Limit	2.39E+03	No Limit	2.39E+03	2.39E+07	No Limit	—	—
Th227	1.11E+02	—	—	1.11E+06	No Limit	5.23E+01	No Limit	5.23E+01	5.23E+05	No Limit	—	—
Th228	4.93E+01	—	—	4.93E+05	No Limit	5.80E+01	No Limit	5.80E+01	5.80E+05	No Limit	—	—
Th229	2.36E+01	—	—	2.36E+05	No Limit	2.39E+03	No Limit	2.39E+03	2.39E+07	No Limit	—	—
Th230	5.80E+01	—	—	5.80E+05	No Limit	5.23E+01	No Limit	5.23E+01	5.23E+05	No Limit	—	—
Th231	2.39E+03	—	—	2.39E+07	No Limit	2.29E+02	No Limit	2.29E+02	2.29E+06	No Limit	—	—
Th232	5.23E+01	—	—	5.23E+05	No Limit	—	No Limit	—	—	No Limit	—	—
Th234	2.29E+02	—	—	2.29E+06	No Limit	—	No Limit	—	—	No Limit	—	—
T1207	—	—	—	—	—	—	—	—	—	—	—	—
T1208	—	—	—	—	—	—	—	—	—	—	—	—
T1209	—	—	—	—	—	—	—	—	—	—	—	—
Tm170	5.92E+02	—	—	5.92E+06	No Limit	7.55E+03	No Limit	7.55E+03	7.55E+07	No Limit	100	1000
Tm171	7.55E+03	—	—	7.55E+07	No Limit	2.53E+01	No Limit	2.53E+01	2.53E+05	No Limit	—	Yes
U230	2.53E+01	—	—	2.53E+05	No Limit	1.81E+01	No Limit	1.81E+01	1.81E+05	No Limit	—	Yes
U232	1.81E+01	—	—	1.81E+05	No Limit	7.35E+01	No Limit	7.35E+01	7.35E+05	No Limit	—	Yes
U233	7.35E+01	—	—	7.35E+05	No Limit	7.47E+01	No Limit	7.47E+01	7.47E+05	No Limit	—	Yes
U234	7.47E+01	—	—	7.47E+05	No Limit	7.59E+01	No Limit	7.59E+01	7.59E+05	No Limit	—	Yes
U235	7.59E+01	—	—	7.59E+05	No Limit	7.88E+01	No Limit	7.88E+01	7.88E+05	No Limit	—	Yes
U236	7.88E+01	—	—	7.88E+05	No Limit	1.08E+03	No Limit	1.08E+03	1.08E+07	No Limit	—	Yes
U237	1.08E+03	—	—	1.08E+07	No Limit	8.25E+01	No Limit	8.25E+01	8.25E+05	No Limit	—	Yes
U238	8.25E+01	—	—	8.25E+05	No Limit	—	—	—	—	—	—	—

Table B-4. (continued).

Individual Concentration (RBC) (mg/L or pCi/L)		Risk Factor (mg/L or pCi/L)		Individual MCL		Beta & Photon Emitters MCL C4 Values										
Constituent		Carcinogenic	Non-Carcinogenic	Carcinogenic	Non-Carcinogenic	Total Body (pCi/L)	GI(LLI) (pCi/L)	GI(S) (pCi/L)	Liver (pCi/L)	Fat (pCi/L)	Thyroid (pCi/L)	Pancreas (pCi/L)	Bone (FRC) (pCi/L)	Marrow (FRC) (pCi/L)	Kidney (pCi/L)	MCL Alpha emitter?
U240		7.51E+02	—	—	7.51E+06	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	Bone	Marrow		
Xe127		—	—	—	—	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	Bone	Marrow		
Xe129m		—	—	—	—	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	Bone	Marrow		
Xe131m		—	—	—	—	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	Bone	Marrow		
Xe133		—	—	—	—	2.92E+06	2.92E+06	2.92E+06	2.92E+06	2.92E+06	2.92E+06	2.92E+06	Bone	Marrow		
Y90		2.92E+02	—	—	—	3.30E+02	3.30E+02	3.30E+02	3.30E+02	3.30E+02	3.30E+02	3.30E+02	Bone	Marrow		
Y91		3.30E+02	—	—	—	4.51E+02	4.51E+02	4.51E+02	4.51E+02	4.51E+02	4.51E+02	4.51E+02	Bone	Marrow		
Zn65		4.51E+02	—	—	—	4.76E+03	4.76E+03	4.76E+03	4.76E+03	4.76E+03	4.76E+03	4.76E+03	Bone	Marrow		
Zr93		4.76E+03	—	—	—	1.15E+03	1.15E+03	1.15E+03	1.15E+03	1.15E+03	1.15E+03	1.15E+03	Bone	Marrow		
Zr95		1.15E+03	—	—	—	—	4.17E-01	4.17E-01	4.17E-01	4.17E-01	4.17E-01	4.17E-01	Bone	Marrow		
1,1,1,1-Trichloroethane		—	—	—	—	5.52E-03	5.52E-03	5.52E+01	5.52E+01	5.52E+01	5.52E+01	5.52E+01	Bone	Marrow		
1,1,1,2,2-Tetrachloroethane		—	—	—	—	1.99E-02	1.99E-02	1.99E+02	1.99E+02	1.99E+02	1.99E+02	1.99E+02	Bone	Marrow		
1,1,1,2-Trichloroethane		—	—	—	—	4.50E-03	4.50E-03	4.50E+01	4.50E+01	4.50E+01	4.50E+01	4.50E+01	Bone	Marrow		
1,1-Dichloroethane		—	—	—	—	1.23E-02	1.23E-02	1.40E-01	1.40E-01	1.40E-01	1.40E-01	1.40E-01	Bone	Marrow		
1,1,1-Dichloroethane		—	—	—	—	4.92E-02	4.92E-02	6.38E-01	6.38E-01	6.38E-01	6.38E-01	6.38E-01	Bone	Marrow		
1,1,2,4-Trichlorobenzene		—	—	—	—	6.11E-01	6.11E-01	4.79E-02	4.79E-02	4.79E-02	4.79E-02	4.79E-02	Bone	Marrow		
1,1,2-Dichlorobenzene		—	—	—	—	5.60E-01	5.60E-01	2.89E-01	2.89E-01	2.89E-01	2.89E-01	2.89E-01	Bone	Marrow		
1,1,2,4-Dichlorobenzene		—	—	—	—	4.92E-02	4.92E-02	7.99E-03	7.99E-03	7.99E-03	7.99E-03	7.99E-03	Bone	Marrow		
1,1,2-Dichloroethene (total)		—	—	—	—	4.50E-03	4.50E-03	4.21E-03	4.21E-03	4.21E-03	4.21E-03	4.21E-03	Bone	Marrow		
1,1,3-Dichlorobenzene		—	—	—	—	6.11E-01	6.11E-01	4.89E-01	4.89E-01	4.89E-01	4.89E-01	4.89E-01	Bone	Marrow		
1,1,4-Dichlorobenzene		—	—	—	—	5.60E-01	5.60E-01	2.60E+00	2.60E+00	2.60E+00	2.60E+00	2.60E+00	Bone	Marrow		
1,4-Dioxane		—	—	—	—	—	—	8.29E-02	8.29E-02	8.29E-02	8.29E-02	8.29E-02	Bone	Marrow		
2,4,5-Trichlorophenol		—	—	—	—	—	—	5.61E-01	5.61E-01	5.61E-01	5.61E-01	5.61E-01	Bone	Marrow		
2,4,6-Trichlorophenol		—	—	—	—	—	—	5.74E-02	5.74E-02	5.74E-02	5.74E-02	5.74E-02	Bone	Marrow		
2,4-Dichlorophenol		—	—	—	—	—	—	5.72E-02	5.72E-02	5.72E-02	5.72E-02	5.72E-02	Bone	Marrow		
2,4-Dimethylphenol		—	—	—	—	—	—	2.87E-02	2.87E-02	2.87E-02	2.87E-02	2.87E-02	Bone	Marrow		
2,4-Dinitrophenol		—	—	—	—	—	—	1.50E+00	1.50E+00	1.50E+00	1.50E+00	1.50E+00	Bone	Marrow		
2,4-Dinitrotoluene		—	—	—	—	—	—	3.66E-01	3.66E-01	3.66E-01	3.66E-01	3.66E-01	Bone	Marrow		
2-Chloronaphthalene		—	—	—	—	—	—	2.39E-02	2.39E-02	2.39E-02	2.39E-02	2.39E-02	Bone	Marrow		
2-Chlorophenol		—	—	—	—	—	—	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	Bone	Marrow		
2-Hexanone		—	—	—	—	—	—	4.52E-01	4.52E-01	4.52E-01	4.52E-01	4.52E-01	Bone	Marrow		
2-Methylnaphthalene		—	—	—	—	—	—	1.41E+00	1.41E+00	1.41E+00	1.41E+00	1.41E+00	Bone	Marrow		
2-Methylphenol		—	—	—	—	—	—	2.74E-04	2.74E-04	2.74E-04	2.74E-04	2.74E-04	Bone	Marrow		
2-Nitroaniline		—	—	—	—	—	—	2.28E-01	2.28E-01	2.28E-01	2.28E-01	2.28E-01	Bone	Marrow		
2-Nitrophenol		—	—	—	—	—	—	—	—	—	—	—	Bone	Marrow		
3,3'-Dichlorobenzidine		1.45E-02	—	—	—	—	—	—	—	—	—	—	Bone	Marrow		
3-Methyl Butanal		—	—	—	—	—	—	—	—	—	—	—	Bone	Marrow		
3-Nitroaniline		—	—	—	—	—	—	2.74E-04	2.74E-04	2.74E-04	2.74E-04	2.74E-04	Bone	Marrow		
3,6-Dinitro-2-methylphenol		—	—	—	—	—	—	5.66E-02	5.66E-02	5.66E-02	5.66E-02	5.66E-02	Bone	Marrow		

Table B-4. (continued).

Constituent	Individual Concentration (RBC) (mg/L or pCi/L)		Risk Factor (mg/L or pCi/L)		Individual MCL		Beta & Photon Emitters MCL C4 Values	
	Carcinogenic	Non-Carcinogenic	Carcinogenic	Non-Carcinogenic	Total Body	GI(LLD)	GI(S)	Liver
					pCi/L or mg/L	(pCi/L)	(pCi/L)	(pCi/L)
								Bone Marrow (FRC) (pCi/L)
								Kidney (pCi/L)
								MCL Alpha emitter?
4-Bromophenyl-phenylether	—	—	1.25E-01	No Limit	1.25E-01	1.41E-01	1.41E-01	
4-Chloro-3-methylphenol	—	—	1.41E-01	No Limit	1.41E-01	2.74E-04	2.74E-04	
4-Chloroaniline	—	—	2.74E-04	No Limit	2.74E-04	2.28E-01	2.28E-01	
4-Chlorophenyl-phenylether	—	—	1.09E-01	No Limit	1.09E-01	1.09E-01	1.09E-01	
4-Methyl-2-Pentanone	—	—	2.28E-01	No Limit	2.28E-01	2.68E-01	2.68E-01	
4-Methylphenol	—	—	2.68E-01	No Limit	2.68E-01	2.80E-01	2.80E-01	
4-Nitroaniline	—	—	2.80E-01	No Limit	2.80E-01	4.80E-01	4.80E-01	
4-Nitrophenol	—	—	4.80E-01	No Limit	4.80E-01	6.25E-02	6.25E-02	
Acenaphthene	—	—	6.25E-02	No Limit	6.25E-02	3.29E-05	3.29E-05	
Acenaphthylene	—	—	3.29E-05	No Limit	3.29E-05	3.88E+01	2.95E-03	
Acetone	—	—	3.88E-03	No Limit	3.88E+01	1.35E+00	1.35E+00	
Acetonitrile	—	—	1.35E+00	No Limit	1.35E+00	1.33E+00	1.33E+00	
Acrolein	—	—	1.33E+00	No Limit	1.33E+00	2.48E+03	2.48E+03	
Acrylonitrile	—	—	8.24E-04	No Limit	8.24E-04	3.92E+02	3.92E+02	
Anthracene	2.48E-01	—	3.51E-04	No Limit	3.51E-04	2.05E+01	3.51E-04	0.000125
Aramite	3.92E-02	—	1.11E-03	No Limit	1.11E+01	1.11E+01	1.11E+01	0.000125
Aroclor-1016	3.92E-02	—	1.11E-03	No Limit	1.11E+01	3.50E+02	3.50E+02	0.005
Aroclor-1254	2.05E-03	—	3.71E-03	No Limit	3.71E+01	2.92E-01	2.92E-01	8.81E-03
Aroclor-1260	2.05E-03	—	8.81E-03	No Limit	8.62E-02	8.62E-02	8.62E-02	0.005
Aroclor-1268	2.92E-05	—	8.62E-02	No Limit	8.62E-02	8.62E-02	8.62E-02	0.005
Benzene	3.50E-02	—	—	No Limit	—	2.88E+00	2.88E+00	0.0002
Benzidine	2.92E-05	—	—	No Limit	—	2.88E+00	2.88E+00	0.0002
Benzo(a)anthracene	3.71E-03	—	—	No Limit	—	2.88E+00	2.88E+00	0.0002
Benzo(a)pyrene	2.88E-04	—	—	No Limit	—	2.88E+00	2.88E+00	0.0002
Benzo(b)fluoranthene	2.88E-03	—	2.01E-01	No Limit	2.01E-01	4.38E+02	4.38E+02	0.0002
Benzo(g,h,i)perylene	—	—	—	No Limit	—	4.38E+02	4.38E+02	0.0002
Benzo(k)fluoranthene	4.38E-02	—	—	No Limit	—	1.14E+02	1.14E+02	0.0002
Benzoic acid	—	—	1.14E+02	No Limit	—	—	—	No Limit
bis(2-Chlorothoxy)methane	—	—	—	No Limit	—	—	—	No Limit
bis(2-Chloroethyl)ether	9.77E-04	—	—	No Limit	—	9.77E+00	9.77E+00	
bis(2-Chloroisopropyl)ether	2.73E-02	—	1.91E-01	No Limit	—	2.73E+02	2.73E+02	
bis(2-Ethylhexyl)phthalate	4.53E-01	—	5.43E-01	No Limit	—	4.53E+03	4.53E+03	
Butane,1,1,3,4-Tetrachloro-Butylbenzylphthalate	—	—	5.10E+00	No Limit	—	—	—	No Limit
Carbazole	2.88E-01	—	—	No Limit	—	2.88E+03	2.88E+03	
Carbon Disulfide	—	—	8.13E-01	No Limit	—	8.13E-01	8.13E-01	
Chlorobenzene	—	—	8.28E-02	No Limit	—	8.28E-02	8.28E-02	0.1
Chloroethane	3.85E-01	—	6.72E+00	No Limit	—	3.85E+03	3.85E+03	6.72E+00
Chloromethane	1.51E-01	—	4.96E-01	No Limit	—	1.51E+03	1.51E+03	4.96E-01

Table B-4. (continued).

Constituent	Individual Concentration (RBC) (mg/L or pCi/L)			Risk Factor (mg/L or pCi/L)			Individual MCL			Beta & Photon Emitters MCL C4 Values		
	Carcinogenic	Non-Carcinogenic	Carcinogenic	Carcinogenic	Non-Carcinogenic	Carcinogenic	Total Body	GI(LLD)	GI(S)	Liver	Fat	Bone
							(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	Marrow (FRC)
Chrysene	9.08E-01	—	—	9.08E+03	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit
Decane, 3,4-Dimethyl	—	—	—	—	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit
Diacetone alcohol	—	—	—	—	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit
Dibenz(a,h)anthracene	1.55E-04	—	—	1.84E-02	1.55E+00	1.84E+02	2.29E+01	2.29E+01	2.29E+01	2.29E+01	2.29E+01	2.29E+01
Dibenzo[furan	—	—	—	2.29E+01	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit
Diethylphthalate	—	—	—	2.87E+02	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit
Dimethyl Disulfide	—	—	—	4.75E-01	4.75E-01	4.75E-01	1.04E-02	1.04E-02	1.04E-02	No Limit	No Limit	No Limit
Dimethylphthalate	—	—	—	1.04E-02	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit
Di-n-butylphthalate	—	—	—	—	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit
Di-n-octylphthalate	—	—	—	—	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit
Eicosane	—	—	—	—	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit
Ethyl cyanide	—	—	—	1.01E+00	1.01E+00	1.01E+00	0.7	0.7	0.7	No Limit	No Limit	No Limit
Ethylbenzene	—	—	—	—	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit
Famphur	—	—	—	—	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit
Fluoranthene	—	—	—	6.94E-01	6.94E-01	6.94E-01	7.90E-01	7.90E-01	7.90E-01	No Limit	No Limit	No Limit
Fluorene	—	—	—	7.90E-01	7.90E-01	7.90E-01	—	—	—	No Limit	No Limit	No Limit
Heptadecane, 2,6,10,15-Tetra	—	—	—	—	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit
Hexachlorobenzene	3.03E-03	1.66E-02	1.66E-02	3.03E+01	3.03E+01	3.03E+01	1.66E-02	1.66E-02	1.66E-02	0.001	0.001	0.001
Hexachlorobutadiene	7.06E-02	7.09E-03	7.09E-03	7.06E+02	7.06E+02	7.06E+02	7.09E-03	7.09E-03	7.09E-03	0.05	0.05	0.05
Hexachlorocyclopentadiene	—	1.92E-01	1.92E-01	No Limit	No Limit	No Limit	1.92E-01	1.92E-01	1.92E-01	0.05	0.05	0.05
Hexachloroethane	4.46E-01	2.68E-02	2.68E-02	4.46E+03	4.46E+03	4.46E+03	2.68E-02	2.68E-02	2.68E-02	0.05	0.05	0.05
Indeno(1,2,3-cd)pyrene	2.05E-03	—	—	2.05E+01	2.05E+01	2.05E+01	No Limit	No Limit	No Limit	0.05	0.05	0.05
Isobutyl alcohol	—	8.60E+00	8.60E+00	No Limit	No Limit	No Limit	8.60E+00	8.60E+00	8.60E+00	0.05	0.05	0.05
Isophorone	7.02E+00	5.72E+00	5.72E+00	7.02E+04	7.02E+04	7.02E+04	No Limit	No Limit	No Limit	0.05	0.05	0.05
Isopropyl Alcohol/2-propanol	—	—	—	3.74E+04	3.74E+04	3.74E+04	3.74E+00	3.74E+00	3.74E+00	No Limit	No Limit	No Limit
Kepone	—	—	—	—	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit
Mesityl oxide	—	—	—	—	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit
Methyl Acetate	—	4.80E+00	4.80E+00	No Limit	No Limit	No Limit	4.80E+00	4.80E+00	4.80E+00	0.05	0.05	0.05
Methylene Chloride	4.26E-01	1.27E+00	1.27E+00	4.26E+03	4.26E+03	4.26E+03	1.27E+00	1.27E+00	1.27E+00	0.05	0.05	0.05
Naphthalene	—	4.89E-03	4.89E-03	No Limit	No Limit	No Limit	4.89E-03	4.89E-03	4.89E-03	0.05	0.05	0.05
Nitrobenzene	—	2.67E-03	2.67E-03	No Limit	No Limit	No Limit	2.67E-03	2.67E-03	2.67E-03	0.05	0.05	0.05
N-Nitrosodiphenylamine	9.56E-04	—	—	9.56E+00	9.56E+00	9.56E+00	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit
N-Nitrosophenylamine	1.29E+00	—	—	1.29E+04	1.29E+04	1.29E+04	1.29E+04	1.29E+04	1.29E+04	No Limit	No Limit	No Limit
Octane,2,3,7-Trimethyl	—	—	—	—	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit
o-Toluenesulfonamide	—	—	—	—	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit
Pentachlorophenol	2.56E-02	3.94E-01	3.94E-01	2.56E+02	2.56E+02	2.56E+02	3.94E-01	3.94E-01	3.94E-01	0.05	0.05	0.05
Phenanthrene	—	5.78E+00	5.78E+00	No Limit	No Limit	No Limit	5.78E+00	5.78E+00	5.78E+00	0.05	0.05	0.05
Phenol	—	1.71E+01	1.71E+01	No Limit	No Limit	No Limit	1.71E+01	1.71E+01	1.71E+01	No Limit	No Limit	No Limit
Phenol,2,6-Bis(1,1-Dimethyl)	—	—	—	—	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit

Alpha emitter?      MCL

Table B-4. (continued).

Constituent	Individual Concentration (RBC) (mg/L or pCi/L)		Risk Factor (mg/L or pCi/L)		Individual MCL		Beta & Photon Emitters MCL C4 Values	
	Carcinogenic	Non-Carcinogenic	Carcinogenic	Carcinogenic	No Limit	Total Body GI(LLI) (pCi/L)	GI(S) (pCi/L)	Liver (pCi/L)
p-Toluenesulfonamide	—	—	5.45E-01	No Limit	5.45E-01			
Pyrene	—	5.91E-02	8.35E-02	No Limit	8.35E-02			
RDX	—	1.27E+00	No Limit	1.27E+00	0.1			
Styrene	1.01E-01	1.89E-01	1.01E+03	No Limit	1.89E-01			
Tetrachloroethene	—	5.66E-01	No Limit	5.66E-01	1			
Toluene	—	—	No Limit	No Limit				
Tributylphosphate	—	—	1.63E+03	2.87E-02	2.87E-02			
Trichloroethene	1.63E-01	2.87E-02	1.63E+03	2.18E+03	1.40E-02			
Trinitrotoluene	2.18E-01	1.40E-02	2.18E+03	2.18E+03	1.40E-02			
Undecane,4,6-Dimethyl-Xylene (ortho)	—	—	1.13E+00	No Limit	No Limit			
Xylene (total)	—	1.13E+00	No Limit	1.13E+00	10			
Aluminum	—	2.88E+01	< Background	< Background				
Antimony	—	1.14E-02	No Limit	1.14E-02	0.006			
Arsenic	4.47E-03	8.63E-03	< Background	< Background	0.006			
Barium	—	1.97E+00	< Background	< Background	0.05			
Beryllium	—	4.57E-02	< Background	< Background	2			
Boron	—	2.59E+00	No Limit	2.59E+00	0.004			
Cadmium	—	1.39E-02	No Limit	1.39E-02	0.005			
Calcium	—	—	< Background	< Background				
Chloride	—	—	No Limit	No Limit				
Chromium	—	—	No Limit	No Limit	0.1			
Cobalt	—	1.73E+00	< Background	< Background				
Copper	—	1.07E+00	No Limit	1.07E+00	1.300			
Cyanide	—	5.76E-01	No Limit	5.76E-01	0.2			
Dysprosium	—	5.76E+00	No Limit	5.76E+00				
Fluoride	—	1.73E+00	No Limit	1.73E+00	4			
Iron	—	8.63E+00	< Background	< Background				
Lead	—	—	No Limit	No Limit	0.015			
Magnesium	—	—	< Background	< Background				
Manganese	—	6.71E-01	< Background	< Background				
Mercury	—	8.42E-03	No Limit	8.42E-03	0.002			
Molybdenum	—	1.44E-01	No Limit	1.44E-01				
Nickel	—	5.51E-01	< Background	< Background				
Nitrate/Nitrite-N	—	4.60E+01	No Limit	4.60E+01	44			
Nitrite	—	2.88E+00	No Limit	2.88E+00	3			
Phosphorus	—	—	< Background	< Background				
Potassium	—	—	No Limit	No Limit				
Selenium	—	1.44E-01	No Limit	1.44E-01	0.05			

Table B-4. (continued).

Constituent	Individual Concentration (RBC) (mg/L or pCi/L)		Risk Factor (mg/L or pCi/L)		Individual MCL		Beta & Photon Emitters MCL C4 Values		Liver (pCi/L)	Thyroid (pCi/L)	Fat (pCi/L)	Pancreas (pCi/L)	Bone (FRC) (pCi/L)	Marrow (FRC) (pCi/L)	Kidney (pCi/L)	Alpha emitter?
	Carcinogenic	Non-Carcinogenic	Carcinogenic	Non-Carcinogenic	Carcinogenic	Non-Carcinogenic	Total Body (pCi/L)	GI(LL) (pCi/L)	GI(S) (pCi/L)							
Silver	—	1.38E-01	No Limit	1.38E-01	< Background	< Background										
Sodium	—	—	—	—	—	—	No Limit	No Limit	1.73E+01							
Strontium	—	1.73E+01	—	—	—	—	No Limit	No Limit	No Limit							
Sulfate	—	—	—	—	—	—	No Limit	No Limit	No Limit							
Sulfide	—	—	—	—	—	—	No Limit	No Limit	No Limit							
Terbium	—	—	—	—	1.90E-03	< Background	< Background	< Background	< Background							
Thallium	—	—	—	—	1.88E-01	< Background	< Background	< Background	< Background							
Vanadium	—	—	—	—	—	—	No Limit	No Limit	No Limit							
Ytterbium	—	—	—	—	8.63E+00	No Limit	No Limit	No Limit	No Limit							
Zinc	—	—	—	—	—	No Limit	No Limit	No Limit	No Limit							
Zirconium	—	—	—	—	—	No Limit	No Limit	No Limit	No Limit							

NA= Not available

--= Not Calculated

< Background = constituent design inventory concentration is less than background and therefore not incorporated into risk evaluations

Table B-5. Comparison of C<sub>t</sub> maximum values and MCL limits.

Constituent	C <sub>t</sub> Maximum Values pCi/L or mg/L	MCL pCi/L or mg/L	Is Maximum C <sub>t</sub> > MCL?
1,1,1-Trichloroethane	4.3E-27	0.2	Yes
1,1,2-Trichloroethane	4.6E-27	0.005	Yes
1,2,4-Trichlorobenzene	4.9E-49	0.07	Yes
1,2-Dichloroethane	9.2E-35	0.005	Yes
Aroclor-1016	0.0E+00	0.000125	Yes
Aroclor-1254	0.0E+00	0.000125	Yes
Aroclor-1260	0.0E+00	0.000125	Yes
Aroclor-1268	0.0E+00	0.000125	Yes
Benzene	5.7E-25	0.005	Yes
Benzo(a)pyrene	0.0E+00	0.0002	Yes
Chlorobenzene	3.2E-48	0.1	Yes
Ethylbenzene	1.5E-72	0.7	Yes
Hexachlorobenzene	0.0E+00	0.001	Yes
Hexachlorocyclopentadiene	0.0E+00	0.05	Yes
Pentachlorophenol	4.6E-26	0.001	Yes
Styrene	1.0E-79	0.1	Yes
Toluene	8.1E-190	1	Yes
Xylene (total)	2.2E-50	10	Yes
Antimony	4.8E-06	0.006	Yes
Arsenic	3.6E-04	0.05	Yes
Barium	1.5E-04	2	Yes
Beryllium	1.4E-08	0.004	Yes
Cadmium	3.0E-06	0.005	Yes
Chromium	3.4E-05	0.1	Yes
Copper	2.5E-05	1.300	Yes
Cyanide	4.0E-05	0.2	Yes
Fluoride	4.6E-04	4	Yes
Lead	2.8E-06	0.015	Yes
Mercury	4.6E-07	0.002	Yes
Nitrate	4.7E-04	44	Yes
Nitrite	1.0E-06	3	Yes
Selenium	7.0E-07	0.05	Yes
Thallium	1.8E-08	0.002	Yes

## **Appendix C**

### **Calculation of Groundwater Risk Based Concentrations**

This page intentionally left blank.

## Appendix C

# Calculation of Groundwater Risk-Based Concentrations

### C.1 Introduction

The purpose of this appendix is to describe the methodology and approach for development of groundwater risk-based concentrations (RBCs) that will be used to develop a set of waste soil concentration limits based on meeting the groundwater remedial action objectives (RAOs) in groundwater downgradient of the Idaho National Engineering and Environmental Laboratory (INEEL) *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) Disposal Facility (ICDF). RBCs were developed for the contaminants in the design inventory, based on a residential exposure scenario.

### C.2 Exposure Scenario

Adult and child residents located downgradient of the ICDF could potentially be exposed to site-related constituents in groundwater through ingestion, dermal contact, and inhalation of volatiles during showering or other household activities. The residential exposure scenario assumes a groundwater ingestion rate of 2 liters per day for adults and 1 liter per day for children, and an exposure frequency of 350 days per year, over a 30 year duration (6 years for a child plus 24 years for an adult).

RBCs for the residential exposure scenario are based on a target excess lifetime cancer risk of  $1 \times 10^{-4}$  for carcinogens or a hazard quotient of 1 for noncarcinogens.

### C.3 Exposure Assumptions

Exposure assumptions for development of groundwater RBCs for the residential scenario are summarized in Table C-1 at the end of this appendix.

### C.3.1 Equations for Non-Radiological Groundwater Risk-Based Concentrations

Groundwater RBCs were calculated in accordance with U.S. Environmental Protection Agency (EPA) guidance (EPA 1991). The following subsections provide the equations used to calculate the RBCs for carcinogens and noncarcinogens.

#### C.3.1.1 Noncarcinogens

Equation (C-1) was used to calculate the groundwater RBCs for noncarcinogenic chemicals:

$$RBC(\text{mg/L}) = \frac{THI \times ATN \times 365 \text{ days/year}}{EF \times \left[ \left( \frac{1}{RfD_o} \times IR_{adj} \right) + \left( \frac{1}{RfD_d} \times CF \times SA_{adj} \times Kp \right) + \left( \frac{1}{RfD_i} \times INH_{adj} \times VF \right) \right]} \quad (\text{C-1})$$

#### C.3.1.2 Carcinogens

Equation (C-2) was used to calculate the groundwater RBCs for carcinogenic chemicals:

$$RBC(\text{mg} / \text{L}) = \frac{TR \times ATC \times 365 \text{ days / year}}{EF \times \left[ \left[ SF_o \times IR_{adj} \right] + \left[ SF_d \times CF \times SA_{adj} \times Kp \right] + \left[ SF_i \times INH_{adj} \times VF \right] \right]} \quad (\text{C-2})$$

where

$$IR_{adj} = \left( \frac{IR_a \times ED_a}{BW_a} \right) + \left( \frac{IR_c \times ED_c}{BW_c} \right)$$

and

$$SA_{adj} = \left( \frac{SA_a \times ET_a \times ED_a}{BW_a} \right) + \left( \frac{SA_c \times ET_c \times ED_c}{BW_c} \right)$$

and

$$INH_{adj} = \left( \frac{INH_a \times ED_a}{BW_a} \right) + \left( \frac{INH_c \times ED_c}{BW_c} \right).$$

Chemical-specific dermal permeability coefficients (Kps) are derived from the *Dermal Exposure Assessment: Principles and Applications* and the *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance Dermal Risk Assessment Interim Guidance* (EPA 1992; EPA 1998).

Volatile constituents considered for the inhalation pathway are operationally defined as those constituents with a Henry's Law Constant greater than  $10^{-5}$  atm-m<sup>3</sup>/mole and a molecular weight less than 200 grams per mole (EPA 1991).

### C.3.2 Equations for Radiological Groundwater Risk-Based Concentrations

Groundwater RBCs were calculated in accordance with EPA guidance (EPA 1991). Only the carcinogenic effects of radionuclides are considered for this evaluation. The following subsections provide the equations used to calculate the RBCs for radiological parameters.

#### C.3.2.1 Carcinogens

Equation (C-3) was used to calculate the groundwater RBCs for carcinogenic chemicals:

$$RBC(\text{pCi} / \text{L}) = \frac{TR}{EF \times \left[ \left[ SF_o \times IR_{adj} \right] + \left[ SF_o \times CF \times SA_{adj} \times Kp \right] \right]} \quad (\text{C-3})$$

where

$$IR_{adj} = (IR_a \times ED_a) + (IR_c \times ED_c)$$

and

$$SA_{adj} = (SA_a \times ET_a \times ED_a) + (SA_c \times ET_c \times ED_c).$$

Chemical-specific dermal permeability coefficients (Kps) for radiological parameters were not available. However, radiological constituents were predicted to behave similarly to metals in groundwater, therefore Kp values for metals were used as surrogate values. Kp values for metals are derived from the *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance Dermal Risk Assessment Interim Guidance* (EPA 1998).

None of the radiological parameters were identified as volatile constituents, therefore the inhalation pathway was not evaluated. Although tritium and radon may be present in household water the amounts inhaled during showering and other water uses is only a fraction of the amounts ingested by drinking of water.

## C.4 Toxicity Values

The primary source of toxicity values is the EPA's Integrated Risk Information System (IRIS) database. If a toxicity value is not available from IRIS, then Health Effects Assessment Summary Tables (HEAST) were used. Toxicity values (i.e., cancer slope factors, inhalation slope factors, oral reference doses, and inhalation reference doses) used to calculate the groundwater RBCs are presented at the end of this appendix in Table C-2 (for non-radiological parameters) and Table C-3 (for radiological parameters) and were obtained from the following sources:

- The Integrated Risk Information System (IRIS), a database available through the EPA National Center for Environmental Assessment (NCEA). IRIS, prepared and maintained by EPA, is an electronic database containing health risk and EPA regulatory information on specific chemicals (EPA 2001).
- The HEAST, provided by the EPA Office of Solid Waste and Emergency Response (EPA, 1997b) is a compilation of toxicity values published in various health effects documents issued by EPA.
- The U.S. EPA Region IX Preliminary Remediation Goal Table (November 2000) at [www.epa.gov/docs/region09/waste/sfund/prg/index.html](http://www.epa.gov/docs/region09/waste/sfund/prg/index.html).

Where available, appropriate surrogate toxicity factors were used for detected chemicals without toxicity factors. 2-nitroaniline was selected as a surrogate for 3-nitroaniline and 4-nitroaniline; 4-nitrophenol was selected as a surrogate for 2-nitrophenol; acenaphthene was selected as a surrogate for acenaphthylene; PCB aroclor 1260 was selected as a surrogate for PCB aroclor 1268; pyrene was selected as a surrogate for benzo(g,h,i)perylene. Use of surrogate toxicity factors assumes the toxicity of structurally similar compounds is equivalent, which may result in an under- or overestimate of risks at the site.

Calcium, magnesium, potassium, and sodium are chemicals considered to be essential nutrients necessary for human nutrition.

RBCs were not calculated for the following nonradiological chemicals because appropriate surrogate toxicity values could not be identified:

- 3-methyl butanal, 4-bromophenyl-phenyl ether, 4-chloro-3-methylphenol, 4-chlorophenyl-phenyl ether, bis (2-chloroethoxy)methane, 1,1,3,4-tetrachlorobutane, 3,4-dimethyl decane, diacetone

alcohol, dimethyl disulfide, eicosane, ethyl cyanide, famphur, 2,6,10,15-tetra heptadecane, isopropyl alcohol/2-propanol, mesityl oxide, 2,3,7-trimethyl octane, o-toluene sulfonamide, 2,6-bis(1,1-dimethyl) phenol, p-toluenesulfonamide, tributylphosphate, 4,6-dimethyl-undecane, chloride, lead, phosphorus, sulfate, sulfide, terbium, ytterbium, and zirconium.

RBCs were not calculated for the following radiological chemicals because slope factors were not available:

- Ac-225, Am-245, At-217, Ba-136m, Bi-212, Cm-241, Cm-242, Cm-243, Cs-134, Cs-135, Cs-136, Cs-137, Eu-154, Ln-114m, Np-235, Po-213, Rb-87, Rh-103m, Se-79, Tb-161, Th-234, and Tl-208.

Lack of appropriate toxicity factors for the above chemicals may result in an underestimation of risks at the site.

## **C.5 Calculation of Cumulative RBCs**

Cumulative risk based concentrations (RBCs) were calculated for each chemical following the development of individual RBCs. Each chemical with an RBC was categorized as either a carcinogen or noncarcinogen. For those chemicals that are considered as both a carcinogen and noncarcinogen, the lower of the two RBCs was selected. Cumulative RBCs for carcinogenic chemicals were derived by dividing the individual RBC for each carcinogen by the total number of carcinogenic chemicals identified. Similarly, cumulative RBCs for noncarcinogens were derived by dividing the individual RBC for each noncarcinogen by the total number of noncarcinogens identified. A summary of the groundwater RBCs developed for non-radiological and radiological constituents are presented at the end of this appendix in Tables C-4 through C-6.

## **C.6 References**

EPA, 1991, Risk Assessment Guidance for Superfund: Volume 1 – Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals), EPA/540/R-92/003, Environmental Protection Agency.

EPA, 1992, Dermal Exposure Assessment: Principles and Applications, EPA/600/8-91/1011B, U.S. Environmental Protection Agency.

EPA, 1997, Health Effects Assessment Summary Tables (HEAST) FY 1997, EPA-540-R-97-036, U.S. Environmental Protection Agency.

EPA, 1998, Risk Assessment Guidance for Superfund: Volume 1 – Human Health Evaluation Manual Supplemental Guidance Dermal Risk Assessment Interim Guidance, U.S. Environmental Protection Agency.

EPA, 2000, Region IX Preliminary Remediation Goal Chemical-Physical Data Table, <http://www.epa.gov/docs/region09/waste/sfund/prg/index.html>, website visited November 2001.

IRIA, 2000, Integrated Risk Information System, EPA National Center for Environmental Assessment (NCEA). <http://www.epa.gov/iris/Table>

Table C-1. Summary of toxicity factors for radiological parameters. Fate and transport modeling results and summary report ICDF.

Table C-1. Summary of exposure assumptions fate and transport modeling results and summary report.  
ICDF

Parameter	Symbol	Residential	Source
Groundwater Risk-Based Concentration (mg/L or pCi/L)	RBC <sub>GW</sub>	Calculated	—
Target Excess Lifetime Cancer Risk	TR	1.00E-04	—
Target Hazard Index	THI	1	—
Exposed individual	—	Adult & Child	—
Body weight - adult (kg)	BW <sub>a</sub>	70	a
- child (kg)	BW <sub>c</sub>	15	a
Groundwater ingestion rate - adult (mg/day)	IR <sub>a</sub>	2	a
- child (mg/day)	IR <sub>c</sub>	1	a
Age-adjusted water intake factor (L-year/kg-day)	IR <sub>adj</sub>	1.09	—
Inhalation rate - adult (m <sup>3</sup> /day)	INH <sub>a</sub>	20	b
- child (m <sup>3</sup> /day)	INH <sub>c</sub>	10	b
Age-adjusted Inhalation Rate (m <sup>3</sup> -year/kg-day)	INH <sub>adj</sub>	1.09	—
Volatilization factor (L/m <sup>3</sup> )	VF	0.5	d
Exposed body parts - adult		Entire Body	—
- child		Entire Body	—
Exposed skin surface area - adult (cm <sup>2</sup> )	SA <sub>a</sub>	18000	c
- child (cm <sup>2</sup> )	SA <sub>c</sub>	6600	c
Age-adjusted surface area (cm <sup>2</sup> -hr-yr/kg)	SA <sub>adj</sub>	1992	—
Exposure time (hour/event) - adult	ET <sub>a</sub>	0.25	c
- child (cm <sup>2</sup> )	ET <sub>c</sub>	0.17	c
Showering event frequency (event/day)		1	c
Dermal permeability constant (cm/hour)	Kp	Chemical-specific	see table
Exposure frequency (days/year)	EF	350	a
Years exposed		30	a
Years over which exposure is averaged - adult	ATN <sub>a</sub>	Noncancer - 24	a
- child	ATN <sub>c</sub>	Noncancer - 6	a
	ATC	Cancer - 70	a

Notes:

- a. Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors. OSWER Directive No. 928.6-03, March 25, 1991.
- b. USEPA Exposure Factors Handbook Volume I, General Factors. Office of Research and Development, EPA/600/P-95/002Fa, August 1997.
- c. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance Dermal Risk Assessment Interim Guidance. Office of Emergency and Remedial Response. Peer Consultation Workshop Draft. November 6, 1998.
- d. Andelman, J. B. 1990. Total Exposure to Volatile Organic Chemicals in Portable Water. N. M. Ram, R. F. Christman, K. P. Cantor (eds). Lewis Publishers.

Table C-2. Summary of toxicity factors for non-radioactive parameters.  
Fate and transport modeling results and summary report ICDF.

Chemical Name	Weight of Evidence Class	Sfo (mg/kg-day) <sup>-1</sup>	Source	RfDo (mg/kg-day)	Source	Sfi (mg/kg-day) <sup>-1</sup>	Source	RfDi (mg/kg-day)	Source	Kp	Source
1,1,1-Trichloroethane	D	--	--	2.00E-02	e	2.86E-01	e	1.70E-02	p		
1,1,2,2-Tetrachloroethane	C	2.00E-01	a	6.00E-02	e	6.00E-02	a	9.00E-03	p		
1,1,2-Trichloroethane	C	5.70E-02	a	4.00E-03	a	4.00E-03	d	8.40E-03	p		
1,1-Dichloroethane	C	--	--	1.00E-01	b	1.43E-01	b	8.90E-03	p		
1,1,2,4-Trichlorobenzene	C	6.00E-01	a	9.00E-03	a	9.00E-03	d	1.60E-02	p		
1,2-Dichlorobenzene	D	--	--	1.00E-02	a	5.70E-02	b	1.00E-01	p		
1,2-Dichlorobenzene	D	--	--	9.00E-02	a	5.71E-02	b	6.10E-02	p		
1,2-Dichloroethane	B2	9.10E-02	a	3.00E-02	e	1.40E-03	e	5.30E-03	p		
1,2-Dichloroethene (total)	--	--	--	1.00E-02	b	1.00E-02	d	1.00E-02	p		
1,3-Dichlorobenzene	D	--	--	9.00E-04	e	9.00E-04	d	8.70E-02	p		
1,4-Dichlorobenzene	C	2.40E-02	b	3.00E-02	e	2.20E-02	e	6.20E-02	p		
1,4-Dioxane	B2	1.10E-02	a	1.10E-02	d	1.10E-02	d	3.60E-04	p		
2,4,5-Trichlorophenol	--	--	--	1.00E-01	a	1.00E-01	d	5.90E-02	f		
2,4,6-Trichlorophenol	B2	1.10E-02	a	1.09E-02	a	--	--	5.00E-02	p		
2,4-Dichlorophenol	--	--	--	3.00E-03	a	--	--	3.00E-03	p		
2,4-Dimethylphenol	--	--	--	2.00E-02	a	--	--	2.00E-02	p		
2,4-Dinitrophenol	--	--	--	2.00E-03	a	--	--	2.00E-03	p		
2,4-Dinitrotoluene	B2	--	--	2.00E-03	a	--	--	3.80E-03	p		
2,6-Dinitrotoluene	B2	--	--	1.00E-03	b	--	--	1.00E-03	p		
2-Butanone	D	--	--	6.00E-01	a	--	--	2.86E-01	a		
2-Chloronaphthalene	B2	--	--	8.00E-02	a	--	--	8.00E-02	d		
2-Chlorophenol	B2	--	--	5.00E-03	a	--	--	5.00E-03	d		
2-Hexanone	--	--	--	4.00E-02	c	--	--	1.40E-03	c		
2-Methylnaphthalene	C	--	--	2.00E-02	c	--	--	--	f		
2-Methylphenol	C	--	--	5.00E-02	a	--	--	5.00E-02	d		
2-Nitroaniline	--	--	--	5.71E-05	d	--	--	5.71E-05	b		
2-Nitrophenol	--	--	--	8.00E-03	g	--	--	8.00E-03	p		
3,3'-Dichlorobenzidine	B2	4.50E-01	a	--	d	4.50E-01	d	--	1.70E-02	p	
3-Methyl Butanal <sup>*</sup>	--	--	--	--	--	--	--	--	--		
3-Nitroaniline	--	--	--	5.71E-05	h	--	--	5.71E-05	h		
4,6-Dinitro-2-methylphenol	--	--	--	2.00E-03	1	--	--	2.00E-03	1		
4-Bromophenyl-phenylether <sup>*</sup>	--	--	--	--	--	--	--	--	2.40E-01	f	
4-Chloro-3-methylphenol <sup>*</sup>	--	--	--	4.00E-03	a	--	--	4.00E-03	d		
4-Chloroaniline	--	--	--	--	--	--	--	--	3.10E-02	f	
4-Chlorophenyl-phenylether <sup>*</sup>	--	--	--	--	--	--	--	--	--		
4-Methyl-2-Pentanone	--	--	--	8.00E-02	b	--	--	2.29E-02	b		
4-Methylphenol	--	--	--	5.00E-03	b	--	--	5.00E-03	d		
4-Nitroaniline	--	--	--	5.71E-05	i	--	--	5.71E-05	i		
4-Nitrophenol	D	--	--	8.00E-03	d	--	--	8.00E-03	d		
Acenaphthene	--	--	--	6.00E-02	a	--	--	6.00E-02	f		
Acenaphthylene	D	--	--	6.00E-02	j	--	--	6.00E-02	j		
Acetone	D	--	--	1.00E-01	a	--	--	1.00E-01	d		

Table C-2. (continued).

Chemical Name	Weight of Evidence Class	Sfo (mg/kg-day) <sup>-1</sup>	Source (mg/kg-day)	RfDo (mg/kg-day)	Sfi (mg/kg-day) <sup>-1</sup>	Source (mg/kg-day)	RfDi (mg/kg-day)	Source (mg/kg-day)	Kp	Source
Acetonitrile	—	—	6.00E-03	a	—	—	1.70E-02	a	6.10E-04	f
Acrolein	C	—	2.00E-02	b	—	—	5.71E-06	a	7.40E-04	p
Acrylonitrile	B1	5.40E-01	a	1.00E-03	b	2.38E-01	a	5.71E-04	a	1.40E-03
Anthracene	D	—	—	3.00E-01	a	—	3.00E-01	d	2.20E-01	f
Aramite	B2	2.50E-02	a	5.00E-02	b	2.49E-02	a	5.00E-02	d	4.60E-02
Aroclor-1016	B2	7.00E-02	a	7.00E-05	a	7.00E-02	a	7.00E-05	d	7.90E-01
Aroclor-1254	B2	2.00E+00	a	2.00E-05	a	2.00E+00	a	2.00E-05	d	3.50E-01
Aroclor-1260	—	2.00E+00	a	—	—	2.00E+00	a	—	1.10E+00	f
Aroclor-1268	—	2.00E+00	o	—	—	2.00E+00	o	—	1.10E+00	o
Benzene	A	5.50E-02	a	3.00E-03	e	2.70E-02	a	1.71E-03	e	2.10E-02
Benzidine	A	2.30E+02	a	3.00E-03	a	2.30E+02	a	3.00E-03	d	1.30E-03
Benz(a)anthracene	B2	7.30E-01	e	—	3.10E-01	e	—	—	8.10E-01	p
Benz(a)pyrene	B2	7.30E+00	a	—	3.10E+00	e	—	—	1.20E+00	p
Benz(b)fluoranthene	B2	7.30E-01	e	—	3.10E-01	e	—	—	1.20E+00	f
Benz(g,h,i)perylene	D	—	—	3.00E-02	k	—	—	1.80E+00	f	1.80E+00
Benz(k)fluoranthene	B2	7.30E-02	e	—	3.10E-02	e	—	—	6.00E-01	f
Benzoic acid	D	—	—	4.00E+00	a	—	—	—	7.30E-03	f
bis(2-Chloroethoxy)methane*	—	—	—	—	—	—	—	—	—	—
bis(2-Chloroethyl)ether	B2	1.10E+00	a	—	—	1.16E+00	a	—	—	2.10E-03
bis(2-Chloroisopropyl)ether	C	7.00E-02	b	4.00E-02	a	3.50E-02	b	4.00E-02	d	1.20E-02
bis(2-Ethylhexyl)phthalate	B2	1.40E-02	a	2.00E-02	a	1.40E-02	e	2.20E-02	d	3.30E-02
Butane, 1,1,3,4-Tetrachloro-Butylbenzylphthalate	C	—	—	—	—	—	—	—	—	—
Carbazole	B2	2.00E-02	b	—	2.00E-01	a	—	2.00E-01	d	7.10E-02
Carbon Disulfide	—	—	—	1.00E-01	a	—	—	2.00E-01	a	2.40E-02
Chlorobenzene	D	—	—	2.00E-02	a	—	—	1.70E-02	e	4.10E-02
Chloroethane	—	2.90E-03	e	4.00E-01	e	2.90E-03	e	2.86E+00	a	8.00E-03
Chloromethane	C	1.30E-02	b	—	6.30E-03	b	8.60E-02	e	4.20E-03	p
Chrysene	B2	7.30E-03	e	—	3.10E-03	e	—	—	8.10E-03	p
Decane, 3,4-Dimethyl*	—	—	—	—	—	—	—	—	—	—
Diacetone alcohol*	—	—	—	—	—	—	—	—	—	—
Dibenz(a,h)anthracene	B2	7.30E+00	e	—	—	—	—	—	—	2.70E+00
Dibenzofuran	D	—	—	4.00E-03	e	—	—	4.00E-03	d	1.50E-01
Diethylphthalate	D	—	—	8.00E-01	a	—	—	8.00E-01	d	4.80E-03
Dimethyl Disulfide*	—	—	—	—	—	—	—	—	—	—
Dimethylphthalate	D	—	—	1.00E+01	a	—	—	1.00E+01	d	1.60E-03
Di-n-butylphthalate	D	—	—	1.00E-01	a	—	—	1.00E-01	d	3.30E-02
Di-n-octylphthalate	—	—	—	2.00E-02	b	—	—	2.00E-02	d	2.70E+01
Eicosane*	—	—	—	—	—	—	—	—	—	—
Ethyl cyanide*	D	—	—	—	—	—	—	—	—	—
Ethylbenzene	—	—	—	1.00E-01	a	—	—	2.90E-01	a	7.40E-02
Famphur*	—	—	—	—	—	—	—	—	—	—
Fluoranthene	D	—	—	4.00E-02	a	—	—	4.00E-02	d	3.60E-01
Fluorene	D	—	—	4.00E-02	a	—	—	4.00E-02	d	2.50E-01

Table C-2. (continued).

Chemical Name	Weight of Evidence Class	Sfo (mg/kg-day) <sup>-1</sup>	Source (mg/kg-day)	RfDo (mg/kg-day)	Sfi (mg/kg-day) <sup>-1</sup>	Source (mg/kg-day)	RfDi (mg/kg-day)	Source (mg/kg-day)	Kp	Source
Heptadecane, 2,6,10,15-Tetra*	—	—	—	—	—	—	—	—	—	—
Hexachlorobenzene	B2	1.60E+00	a	8.00E-04	a	1.61E+00	a	8.00E-04	d	2.10E-01
Hexachlorobutadiene	C	7.80E-02	a	3.00E-04	e	7.80E-02	a	3.00E-04	d	1.20E-01
Hexachlorocyclopentadiene	D	—	—	7.00E-03	a	—	—	2.00E-05	b	2.90E-02
Hexachloroethane	C	1.40E-02	a	1.00E-03	a	1.40E-02	a	1.00E-03	d	4.20E-02
Indeno(1,2,3-cd)pyrene	B2	7.30E-01	e	—	—	3.10E-01	e	—	—	1.90E+00
Isobutyl alcohol	—	—	—	3.00E-01	a	—	—	3.00E-01	d	2.60E-03
Isophorone	C	9.50E-04	a	2.00E-01	a	9.50E-04	e	2.00E-01	d	4.40E-03
Isopropyl Alcohol/2-propanol*	—	—	—	—	—	—	—	8.90E-04	f	—
Kepone	—	—	—	1.80E+01	e	—	—	—	—	—
Mesityl oxide*	—	—	—	—	—	—	—	—	—	—
Methyl Acetate	—	—	—	1.00E+00	b	—	—	—	—	—
Methylene Chloride	B2	7.50E-03	a	6.00E-02	a	1.65E-03	a	8.57E-01	b	4.50E-03
Naphthalene	C	—	—	2.00E-02	a	—	—	8.57E-04	a	6.90E-02
Nitrobenzene	B2	—	—	5.00E-04	a	—	—	5.71E-04	b	6.90E-03
N-Nitroso-di-n-propylamine	B2	7.00E+00	a	—	—	7.00E+00	d	—	—	2.80E-03
N-Nitrosodiphenylamine	B2	4.90E-03	a	—	—	4.90E-03	d	—	—	3.60E-02
Octane,2,3,7-Trimethyl*	—	—	—	—	—	—	—	—	—	—
o-Toluenesulfonamide*	—	—	—	—	—	—	—	—	—	—
Pentachlorophenol	B2	1.20E-01	a	3.00E-02	a	1.20E-01	d	3.00E-02	d	6.50E-01
Phenanthrene	D	—	—	3.00E-01	a	—	—	3.00E-01	d	2.70E-01
Phenol	D	—	—	6.00E-01	a	—	—	6.00E-01	d	5.50E-03
Phenol,2,6-Bis(1,1-Dimethyl)*	—	—	—	—	—	—	—	—	—	—
p-Toluenesulfonamide*	—	—	—	—	—	—	—	—	—	—
Pyrene	D	—	—	3.00E-02	a	—	—	3.00E-02	d	3.20E-01
Styrene	C	—	—	2.00E-01	a	—	—	2.90E-01	a	5.50E-02
Tetrachloroethene	C-B2	5.20E-02	e	1.00E-02	a	2.03E-03	e	1.14E-01	e	4.80E-02
Toluene	D	—	—	2.00E-01	a	—	—	1.10E-01	b	4.50E-02
Tributylphosphate*	—	—	—	—	—	—	—	—	—	—
Trichloroethene	B2	1.10E-02	e	6.00E-03	a	6.00E-03	e	6.00E-03	d	1.60E-02
Undecane,4,6-Dimethyl*	—	—	—	—	—	—	—	—	—	—
Xylene (ortho)	—	—	—	2.00E+00	a	—	—	2.00E-01	a	8.00E-02
Xylene (total)	D	—	—	2.00E+00	a	—	—	2.00E-01	a	8.00E-02
Trinitrotoluene	—	3.00E-02	a	5.00E-04	a	3.00E-02	d	5.00E-04	d	1.60E-02
RDX	—	1.10E-01	a	3.00E-03	a	1.10E-01	d	3.00E-03	d	1.90E-02
Antimony	D	—	—	4.00E-04	a	—	—	—	—	1.00E-03
Arsenic	A	1.50E+00	a	3.00E-04	a	1.51E+01	a	—	—	1.00E-03
Barium	D	—	—	7.00E-02	a	—	—	—	b	1.00E-03
Beryllium	B1	—	—	2.00E-03	a	—	—	—	a	1.00E-03
Boron	D	—	—	9.00E-02	a	—	—	—	b	1.00E-03
Cadmium	B1	—	—	5.00E-04	a	6.30E+00	a	—	—	1.00E-03
Calcium*	—	—	—	—	—	—	—	—	—	1.00E-03
Chloride*	—	—	—	—	—	—	—	—	—	1.00E-03
Chromium	A	—	—	—	—	—	—	4.20E+01	a	—

Table C-2. (continued).

Chemical Name	Weight of Evidence Class	Sfo (mg/kg-day) <sup>-1</sup>	RfDo (mg/kg-day)	Sfi (mg/kg-day) <sup>-1</sup>	RfDi (mg/kg-day)	Kp	Source
Cobalt	—	—	6.00E-02	—	—	1.00E-03	p
Copper	D	—	3.71E-02	b	—	1.00E-03	p
Cyanide	—	—	—	a	—	—	—
Dysprosium	—	—	2.00E-02	a	—	—	—
Fluoride	—	—	2.00E-01	e	—	—	—
Iron	—	—	6.00E-02	a	—	—	—
Lead*	—	—	3.00E-01	e	—	1.00E-03	p
Magnesium*	—	—	—	—	—	1.00E-03	p
Manganese	D	—	2.40E-02	a	—	1.00E-03	p
Mercury	D	—	3.00E-04	a	—	1.00E-03	p
Molybdenum	—	—	5.00E-03	b	—	1.00E-03	p
Nickel	D	—	2.00E-02	a	—	1.00E-03	p
Nitrate	—	—	1.00E-01	a	—	—	—
Nitrate/Nitrite-N*	—	—	—	—	—	—	—
Nitrite	—	—	1.00E-01	a	—	—	—
Phosphorus*(q)	—	—	—	—	—	1.00E-03	p
Potassium*	—	—	—	—	—	1.00E-03	p
Selenium	D	—	5.00E-03	a	—	1.00E-03	p
Silver	D	—	5.00E-03	a	—	1.00E-03	p
Sodium*	—	—	—	—	—	1.00E-03	p
Strontium	—	—	6.00E-01	a	—	1.00E-03	p
Sulfate*	—	—	—	—	—	—	—
Sulfide*	—	—	—	—	—	—	—
Terbium*	—	—	—	—	—	—	—
Thallium	D	—	6.60E-05	a	—	1.00E-03	p
Vanadium	—	—	7.00E-03	b	—	1.00E-03	p
Ytterbium*	—	—	—	—	—	1.00E-03	p
Zinc	D	—	3.00E-01	a	—	1.00E-03	p
Zirconium*	—	—	—	—	—	1.00E-03	p

Notes:

- a. U.S. EPA. The Integrated Risk Information System (IRIS, 2000), a database available through the EPA National Center for Environmental Assessment (NCEA). <http://www.epa.gov/iris/>
- b. U.S. EPA. Health Effects Assessment Summary Tables (HEAST) FY 1997 update. EPA-540-R-97-036. July 1997.
- c. U.S. EPA Region III RBC Tables. April 1999. <http://www.epareg3hwmd/risk/>
- d. Route to route extrapolation
- e. U.S. EPA Region IX Preliminary Remediation Goals Table. November 22, 2000. [http://www.epa.gov/region09/waste/stfund/prg/s1\\_01.htm](http://www.epa.gov/region09/waste/stfund/prg/s1_01.htm)
- f. Oak Ridge National Laboratory. October 2001. [http://risk.lsd.ornl.gov/rap\\_hp.shtml](http://risk.lsd.ornl.gov/rap_hp.shtml)
- g. Toxicity factors for 4-nitrophenol were used as surrogates for 2-nitrophenol
- h. Toxicity factors for 2-nitroaniline were used as surrogates for 3-nitroaniline
- i. Toxicity factors for 2-nitroaniline were used as surrogates for 4-nitroaniline
- j. Toxicity factors for acenaphthene were used as surrogates for acenaphthylene
- k. Toxicity factors for pyrene were used as surrogates for benzog(h)perylene
- l. Toxicity factors for 2,4-dinitrophenol were used as surrogates for 4,6-dinitro-2-methylphenol.
- m. U.S. EPA Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance Dermal Risk Assessment. November 6, 1998.
- n. U.S. Environmental Protection Agency, 1996. Superfund Soil Screening Guidance: User's Guide, Second Edition. Office of Solid Waste and Emergency Response Publication 9355.4-35. July 1996.
- o. Toxicity factors for aroclor 1260 were used as surrogates for aroclor 1268.
- p. EPA. Dermal Exposure Assessment: Principles and Applications. Interim Report. EPA/600/R-91/011B. January 1992.
- q. The reference dose for phosphorus is based on exposure to elemental phosphorus. Elemental phosphorus is unstable in the environment and rapidly oxidizes to the phosphate or orthophosphate oxyanion. Phosphorus present in the soil at this site is assumed to be either the phosphate ion or insoluble mineral species, which do not have reference doses established. Therefore, phosphorus is excluded from assessment in risk-based concentration.
- \* No toxicity factors available for this chemical
- = not applicable or not available

Table C-3. Summary of toxicity factors for radiological parameters.  
Fate and transport modeling results and summary report.  
ICDF

Isotope <sup>a</sup>	Oral Slope Factor (risk/pCi) <sup>b,c</sup>	Kp <sup>d</sup>
Ac225	—	1.00E-03
Ac227	5.59E-12	1.00E-03
Ac228	1.89E-10	1.00E-03
Ag106	6.92E-11	6.00E-04
Ag108	2.01E-10	6.00E-04
Ag108m	4.86E-10	6.00E-04
Ag109m	1.99E-12	6.00E-04
Ag110	7.25E-14	6.00E-04
Ag110m	1.20E-13	6.00E-04
Ag111	1.65E-13	6.00E-04
Am241	1.21E-13	1.00E-03
Am242	1.77E-12	1.00E-03
Am242m	5.92E-14	1.00E-03
Am243	4.81E-12	1.00E-03
Am245	—	1.00E-03
Am246	8.14E-12	1.00E-03
At217	—	1.00E-03
Ba136m	—	1.00E-03
Ba137m	9.88E-12	1.00E-03
Ba140	8.21E-12	1.00E-03
Be 10	1.99E-12	1.00E-03
Bi210	1.40E-13	1.00E-03
Bi211	1.73E-11	1.00E-03
Bi212	—	1.00E-03
Bi213	5.07E-14	1.00E-03
Bi214	9.62E-14	1.00E-03
Bk249	1.38E-12	1.00E-03
Bk250	2.59E-12	1.00E-03
C 14	1.04E-10	1.00E-03
Cd109	1.79E-12	1.00E-03
Cd113m	7.07E-11	1.00E-03
Cd115m	1.04E-10	1.00E-03
Ce141	1.03E-10	1.00E-03
Ce142	1.08E-10	1.00E-03
Ce144	2.52E-12	1.00E-03
Cf249	5.11E-14	1.00E-03
Cf250	2.22E-13	1.00E-03
Cf251	1.23E-13	1.00E-03
Cf252	6.59E-14	1.00E-03
Cm241	—	1.00E-03
Cm242	—	1.00E-03
Cm243	—	1.00E-03
Cm244	1.05E-13	1.00E-03
Cm245	3.20E-13	1.00E-03
Cm246	2.28E-12	1.00E-03
Cm247	1.02E-11	1.00E-03
Cm248	1.56E-12	1.00E-03

Table C-3. (continued).

Isotope <sup>a</sup>	Oral Slope Factor (risk/pCi) <sup>b,c</sup>	Kp <sup>d</sup>
Cm250	6.70E-12	1.00E-03
Co-57	9.66E-12	4.00E-04
Co-58	2.50E-12	4.00E-04
Co-60	6.33E-13	4.00E-04
Cr-51	6.96E-13	1.00E-03
Cs132	3.37E-11	1.00E-03
Cs134	—	1.00E-03
Cs135	—	1.00E-03
Cs136	—	1.00E-03
Cs137	—	1.00E-03
Er169	7.36E-13	1.00E-03
Eu150	1.66E-12	1.00E-03
Eu152	1.50E-12	1.00E-03
Eu154	—	1.00E-03
Eu155	6.29E-12	1.00E-03
Eu156	7.44E-12	1.00E-03
Fe-59	2.78E-12	1.00E-03
Fr221	1.55E-13	1.00E-03
Fr223	5.44E-12	1.00E-03
Gd152	4.33E-14	1.00E-03
Gd153	8.51E-13	1.00E-03
H 3	1.52E-11	1.00E-03
Hf-181	2.00E-12	1.00E-03
Ho166m	9.25E-15	1.00E-03
I129	6.81E-12	1.00E-03
I131	3.19E-12	1.00E-03
In114	2.56E-12	1.00E-03
In114m	—	1.00E-03
In115	3.70E-13	1.00E-03
In115m	1.49E-11	1.00E-03
K-40	2.14E-13	2.00E-04
Kr81	9.29E-14	1.00E-03
Kr85	7.03E-12	1.00E-03
La138	8.66E-14	1.00E-03
La140	1.52E-13	1.00E-03
Mn-54	4.22E-13	1.00E-03
Nb93m	2.65E-13	1.00E-03
Nb94	1.92E-12	1.00E-03
Nb92	3.32E-12	1.00E-03
Nb95	7.73E-12	1.00E-03
Nb95m	5.66E-12	1.00E-03
Nd144	8.92E-12	1.00E-03
Nd147	5.51E-11	1.00E-03
Np235	—	1.00E-03
Np236	7.10E-13	1.00E-03
Np237	5.11E-13	1.00E-03
Np238	1.92E-13	1.00E-03
Np239	3.43E-12	1.00E-03
Np240	2.01E-12	1.00E-03
Np240m	1.24E-10	1.00E-03
Pa231	1.11E-12	1.00E-03

Table C-3. (continued).

Isotope <sup>a</sup>	Oral Slope Factor (risk/pCi) <sup>b,c</sup>	Kp <sup>d</sup>
Pa233	5.66E-13	1.00E-03
Pa234	1.50E-13	1.00E-03
Pa234m	2.46E-13	1.00E-03
Pb209	1.57E-13	1.00E-04
Pb210	1.45E-12	1.00E-04
Pb211	3.01E-13	1.00E-04
Pb212	4.70E-14	1.00E-04
Pb214	2.82E-13	1.00E-04
Pd107	1.71E-12	1.00E-03
Pm146	8.44E-14	1.00E-03
Pm147	1.48E-13	1.00E-03
Pm148	4.07E-14	1.00E-03
Pm148m	1.55E-12	1.00E-03
Po210	3.53E-13	1.00E-03
Po211	2.47E-12	1.00E-03
Po212	7.55E-12	1.00E-03
Po213	—	1.00E-03
Po214	1.72E-13	1.00E-03
Po215	3.50E-13	1.00E-03
Po216	5.00E-12	1.00E-03
Po218	2.28E-11	1.00E-03
Pr143	2.87E-11	1.00E-03
Pr144	8.66E-12	1.00E-03
Pr144m	1.70E-11	1.00E-03
Pu236	1.37E-12	1.00E-03
Pu237	1.22E-12	1.00E-03
Pu238	1.59E-11	1.00E-03
Pu239	3.81E-12	1.00E-03
Pu240	1.31E-13	1.00E-03
Pu241	3.47E-12	1.00E-03
Pu242	1.35E-12	1.00E-03
Pu243	4.63E-12	1.00E-03
Pu244	7.10E-12	1.00E-03
Pu246	3.52E-11	1.00E-03
Ra222	3.53E-11	1.00E-03
Ra223	1.25E-13	1.00E-03
Ra224	2.11E-11	1.00E-03
Ra225	4.44E-11	1.00E-03
Ra226	1.27E-10	1.00E-03
Ra228	8.62E-11	1.00E-03
Rb86	1.32E-10	1.00E-03
Rb87	—	1.00E-03
Rh102	4.26E-12	1.00E-03
Rh103m	—	1.00E-03
Rh106	3.30E-12	1.00E-03
Rn218	1.93E-13	1.00E-03
Rn219	1.52E-13	1.00E-03
Rn220	3.28E-13	1.00E-03
Rn222	3.49E-11	1.00E-03
Ru103	4.85E-12	1.00E-03
Ru106	3.85E-11	1.00E-03

Table C-3. (continued).

Isotope <sup>a</sup>	Oral Slope Factor (risk/pCi) <sup>b,c</sup>	Kp <sup>d</sup>
Sb124	9.47E-11	1.00E-03
Sb125	8.36E-11	1.00E-03
Sb126	1.04E-10	1.00E-03
Sb126m	1.02E-10	1.00E-03
Sc-46	9.95E-11	1.00E-03
Se 79	—	1.00E-03
Sm146	8.40E-14	1.00E-03
Sm147	4.63E-12	1.00E-03
Sm148	1.01E-11	1.00E-03
Sm149	1.04E-12	1.00E-03
Sm151	2.95E-12	1.00E-03
Sn117m	1.26E-13	1.00E-03
Sn119m	1.57E-11	1.00E-03
Sn121m	2.66E-15	1.00E-03
Sn123	2.43E-13	1.00E-03
Sn125	8.25E-14	1.00E-03
Sn126	7.44E-13	1.00E-03
Sr89	1.35E-13	1.00E-03
Sr90	1.85E-13	1.00E-03
Tb160	5.96E-14	1.00E-03
Tb161	—	1.00E-03
Tc 98	6.51E-14	1.00E-03
Tc 99	—	1.00E-03
Te123	1.85E-13	1.00E-03
Te123m	4.74E-14	1.00E-03
Te125m	1.86E-13	1.00E-03
Te127	1.46E-12	1.00E-03
Te127m	4.22E-11	1.00E-03
Te129	4.14E-14	1.00E-03
Te129m	4.74E-12	1.00E-03
Th226	4.51E-14	1.00E-03
Th227	8.66E-12	1.00E-03
Th228	3.04E-11	1.00E-03
Th229	3.04E-11	1.00E-03
Th230	1.58E-13	1.00E-03
Th231	1.37E-13	1.00E-03
Th232	4.63E-13	1.00E-03
Th234	—	1.00E-03
Tl207	6.40E-13	1.00E-03
Tl208	—	1.00E-03
Tl209	1.94E-12	1.00E-03
Tm170	5.25E-13	1.00E-03
Tm171	2.26E-13	1.00E-03
U230	5.29E-13	1.00E-03
U232	4.14E-13	1.00E-03
U233	1.11E-11	1.00E-03
U234	3.15E-13	1.00E-03
U235	8.95E-14	1.00E-03
U236	2.53E-12	1.00E-03
U237	2.02E-12	1.00E-03
U238	5.99E-12	1.00E-03

Table C-3. (continued).

Isotope <sup>a</sup>	Oral Slope Factor (risk/pCi) <sup>b,c</sup>	Kp <sup>d</sup>
U240	5.96E-14	1.00E-03
Xe127	1.02E-12	1.00E-03
Xe129m	3.49E-11	1.00E-03
Xe131m	5.51E-11	1.00E-03
Xe133	2.73E-11	1.00E-03
Y90	2.73E-12	1.00E-03
Y91	4.55E-12	1.00E-03
Zn65	2.02E-12	1.00E-03
Zr93	4.29E-12	1.00E-03
Zr95	5.14E-13	1.00E-03

**Note:**

a. For each radionuclide listed, slope factors correspond to the risks per unit intake or exposure for that radionuclide only, except when marked with a “+D” to indicate that the risks from associated short-lived radioactive decay products (i.e., those decay products with radioactive half-lives less than or equal to 6 months) are also included. Refer to Exhibit 1 in the User’s Guide section on radionuclide carcinogenicity for guidance on determining slope factors for partial or complete radioactive decay chains.

b. The curie (Ci), the customary unit of activity is equal to  $3.7 \times 10^{10}$  nuclear transformations per second. 1 picocurie (pCi) =  $10^{-12}$  Ci. The International System (SI) unit of activity is the becquerel (1 Bq = 1 nuclear transformation per second).

c. EPA. Radiation Protection Programs, Radiation Slope Factors at the web site <http://www.epa.gov/radiation/heast/>

d. EPA guidance recommends using a default Kp of  $1 \times 10^{-3}$  cm/hr for inorganic compounds unless otherwise noted. Source: Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual, Supplemental Guidance, Dermal Risk Assessment, Interim Guidance, EPA, November 6, 1998.

For radioisotopes of iodine, the values listed for food ingestion represent ingestion of milk; corresponding values for ingestion of nondairy foods would be lower by a factor of approximately 2.

For radioisotopes of mercury, Federal Guidance Report No. 13 provides values for inorganic compounds, organic compounds, and methyl mercury for ingestion of each isotope. The ingestion values reported in Table 4 for each isotope represent the maximum of these three forms.

For radioisotopes of polonium, Federal Guidance Report No. 13 provides values for ingestion of organic ( $f_l = 0.5$ ) and inorganic ( $f_l = 0.1$ ) compounds. For purposes of this tabulation, polonium is assumed to be ingested in organic form in foods and in inorganic form in water and soil.

For radioisotopes of sulfur, Federal Guidance Report no. 13 provides values for ingestion of both organic and inorganic compounds. For the purpose of this tabulation, sulfur is assumed to be ingested in organic form in foods and in inorganic form for ingestion of water and soil.

Table C-4. Summary of groundwater carcinogenic RBCs for non-radiological parameters.

ICDF	Residential Exposure Scenario	
	Chemical	Individual RBC (mg/L)
	1,1,2,2-Tetrachloroethane	5.52E-03
	1,1,2-Trichloroethane	1.99E-02
	1,1-Dichloroethene	4.50E-03
	1,4-Dichlorobenzene	4.92E-02
	1,4-Dioxane	6.11E-01
	2,4,6-Trichlorophenol	5.60E-01
	3,3'-Dichlorobenzidine	1.45E-02
	Aramite	2.48E-01
	Aroclor-1260	1.11E-03
	Aroclor-1268	1.11E-03
	Benzidine	2.92E-05
	Benzo(a)anthracene	3.71E-03
	Benzo(a)pyrene	2.88E-04
	Benzo(b)fluoranthene	2.88E-03
	Benzo(k)fluoranthene	4.38E-02
	bis(2-Chloroethyl)ether	9.77E-04
	bis(2-Chloroisopropyl)ether	2.73E-02
	bis(2-Ethylhexyl)phthalate	4.53E-01
	Carbazole	2.88E-01
	Chloroethane	3.85E-01
	Chloromethane	1.51E-01
	Chrysene	9.08E-01
	Dibenz(a,h)anthracene	1.55E-04
	Hexachlorobenzene	3.03E-03
	Indeno(1,2,3-cd)pyrene	2.05E-03
	Methylene Chloride	4.26E-01
	N-Nitroso-di-n-propylamine	9.56E-04
	N-Nitrosodiphenylamine	1.29E+00
	Pentachlorophenol	2.56E-02
	Tetrachloroethene	1.01E-01
	RDX	5.91E-02
	Arsenic	4.47E-03

Table C-5. Summary of groundwater noncarcinogenic RBCs for non-radiological parameters.  
Residential Exposure Scenario

ICDF

Chemical	Individual RBC (mg/L)
1,1,1-Trichloroethane	4.17E-01
1,1-Dichloroethane	6.38E-01
1,2,4-Trichlorobenzene	1.40E-01
1,2-Dichlorobenzene	2.89E-01
1,2-Dichloroethane	7.99E-03
1,2-Dichloroethene (total)	4.79E-02
1,3-Dichlorobenzene	4.21E-03
2,4,5-Trichlorophenol	2.60E+00
2,4-Dichlorophenol	8.29E-02
2,4-Dimethylphenol	5.61E-01
2,4-Dinitrophenol	5.74E-02
2,4-Dinitrotoluene	5.72E-02
2,6-Dinitrotoluene	2.87E-02
2-Butanone	1.50E+00
2-Chloronaphthalene	3.66E-01
2-Chlorophenol	2.39E-02
2-Hexanone	1.14E+00
2-Methylnaphthalene	4.52E-01
2-Methylphenol	1.41E+00
2-Nitroaniline	2.74E-04
2-Nitrophenol	2.28E-01
3-Nitroaniline	2.74E-04
4,6-Dinitro-2-methylphenol	5.66E-02
4-Chloroaniline	1.09E-01
4-Methyl-2-Pentanone	1.25E-01
4-Methylphenol	1.41E-01
4-Nitroaniline	2.74E-04
4-Nitrophenol	2.28E-01
Acenaphthene	2.68E-01
Acenaphthylene	2.80E-01
Acetone	4.80E-01
Acetonitrile	6.25E-02
Acrolein	3.29E-05
Acrylonitrile	2.95E-03

Table C-5. (continued).

ICDF	Residential Exposure Scenario	
	Chemical	Individual RBC (mg/L)
	Anthracene	1.35E+00
	Aroclor-1016	8.24E-04
	Aroclor-1254	3.51E-04
	Benzene	8.81E-03
	Benzo(g,h,i)perylene	2.01E-01
	Benzoic acid	1.14E+02
	Butylbenzylphthalate	5.10E+00
	Carbon Disulfide	8.13E-01
	Chlorobenzene	8.28E-02
	Dibenzofuran	1.84E-02
	Diethylphthalate	2.29E+01
	Dimethylphthalate	2.87E+02
	Di-n-butylphthalate	4.75E-01
	Di-n-octylphthalate	1.04E-02
	Ethylbenzene	1.01E+00
	Fluoranthene	6.94E-01
	Fluorene	7.90E-01
	Hexachlorobutadiene	7.09E-03
	Hexachlorocyclopentadiene	1.92E-01
	Hexachloroethane	2.68E-02
	Isobutyl alcohol	8.60E+00
	Isophorone	5.72E+00
	Methyl Acetate	4.80E+00
	Naphthalene	4.89E-03
	Nitrobenzene	2.67E-03
	Phenanthrene	5.78E+00
	Phenol	1.71E+01
	Pyrene	5.45E-01
	Styrene	1.27E+00
	Toluene	5.66E-01
	Trichloroethene	2.87E-02
	Xylene (ortho)	1.13E+00
	Xylene (total)	1.13E+00
	Trinitrotoluene	1.40E-02
	Aluminum	2.88E+01

Table C-5. (continued).

ICDF	Residential Exposure Scenario	
	Chemical	Individual RBC (mg/L)
	Antimony	1.14E-02
	Barium	1.97E+00
	Beryllium	4.57E-02
	Boron	2.59E+00
	Cadmium	1.39E-02
	Cobalt	1.73E+00
	Copper	1.07E+00
	Iron	8.63E+00
	Manganese	6.71E-01
	Mercury	8.42E-03
	Molybdenum	1.44E-01
	Nickel	5.51E-01
	Nitrate	4.60E+01
	Nitrite	2.88E+00
	Selenium	1.44E-01
	Silver	1.38E-01
	Strontium	1.73E+01
	Thallium	1.90E-03
	Vanadium	1.88E-01
	Zinc	8.63E+00

Table C-6. Summary of groundwater carcinogenic RBCs for radiological parameters.

Residential Exposure Scenario

ICDF

Chemical	Individual RBC (mg/L)
Ac225	2.79E+01
Ac227	2.63E+01
Ac228	2.65E+03
Ag106	8.93E+04
Ag108	—
Ag108m	6.49E+02
Ag109m	—
Ag110	—
Ag110m	5.35E+02
Ag111	6.44E+02
Am241	5.08E+01
Am242	2.95E+03
Am242m	7.47E+01
Am243	5.13E+01
Am245	2.38E+04
Am246	4.29E+04
At217	—
Ba136m	—
Ba137m	—
Ba140	3.54E+02
Be 10	7.51E+02
Bi210	5.92E+02
Bi211	—
Bi212	7.44E+03
Bi213	1.03E+04
Bi214	2.75E+04
Bk249	4.76E+03
Bk250	9.33E+03
C 14	3.41E+03
Cd109	1.06E+03
Cd113m	1.84E+02
Cd115m	3.11E+02
Ce141	1.14E+03

Table C-6. (continued).

Chemical	Residential Exposure Scenario	Individual RBC (mg/L)
Ce142		—
Ce144		1.50E+02
Cf249		4.16E+01
Cf250		6.13E+01
Cf251		4.00E+01
Cf252		—
Cm241		1.09E+03
Cm242		1.37E+02
Cm243		5.58E+01
Cm244		6.32E+01
Cm245		5.08E+01
Cm246		5.18E+01
Cm247		5.31E+01
Cm248		—
Cm250		—
Co-57		5.08E+03
Co-58		1.79E+03
Co-60		3.37E+02
Cr-51		2.85E+04
Cs132		3.62E+03
Cs134		1.25E+02
Cs135		1.11E+03
Cs136		6.10E+02
Cs137		1.74E+02
Er169		2.09E+03
Eu150		2.22E+03
Eu152		8.70E+02
Eu154		5.13E+02
Eu155		2.78E+03
Eu156		4.16E+02
Fe-59		6.70E+02
Fr221		—
Fr223		7.24E+02
Gd152		1.78E+02

Table C-6. (continued).

Chemical	Residential Exposure Scenario	Individual RBC (mg/L)
Gd153		3.47E+03
H 3		1.04E+05
Hf-181		8.30E+02
Ho166m		5.73E+02
I129		3.57E+01
I131		1.16E+02
In114		—
In114m		2.13E+02
In115		1.56E+02
In115m		1.20E+04
K-40		2.14E+02
Kr81		—
Kr85		—
La138		1.50E+03
La140		4.80E+02
Mn-54		2.32E+03
Nb93m		6.58E+03
Nb94		6.80E+02
Nb92		—
Nb95		2.16E+03
Nb95m		1.44E+03
Nd144		—
Nd147		7.59E+02
Np235		1.53E+04
Np236		5.03E+02
Np237		8.54E+01
Np238		9.78E+02
Np239		1.03E+03
Np240		2.37E+04
Np240m		—
Pa231		3.05E+01
Pa233		9.51E+02
Pa234		2.06E+03
Pa234m		—

Table C-6. (continued).

Chemical	Residential Exposure Scenario	Individual RBC (mg/L)
Pb209		2.19E+04
Pb210		6.00E+00
Pb211		1.29E+04
Pb212		2.12E+02
Pb214		1.54E+04
Pd107		2.11E+04
Pm146		1.26E+03
Pm147		3.12E+03
Pm148		3.07E+02
Pm148m		6.61E+02
Po210		1.40E+01
Po211		—
Po212		—
Po213		—
Po214		—
Po215		—
Po216		—
Po218		—
Pr143		6.67E+02
Pr144		6.52E+04
Pr144m		—
Pu236		7.07E+01
Pu237		9.15E+03
Pu238		4.03E+01
Pu239		3.91E+01
Pu240		3.91E+01
Pu241		3.00E+03
Pu242		4.12E+01
Pu243		1.11E+04
Pu244		3.85E+01
Pu246		3.05E+02
Ra222		—
Ra223		2.22E+01
Ra224		3.16E+01

Table C-6. (continued).

Chemical	Residential Exposure Scenario	Individual RBC (mg/L)
Ra225		4.63E+01
Ra226		1.37E+01
Ra228		5.08E+00
Rb86		5.34E+02
Rb87		1.01E+03
Rh102		6.86E+02
Rh103m		5.62E+05
Rh106		—
Rn218		—
Rn219		—
Rn220		—
Rn222		—
Ru103		1.37E+03
Ru106		1.25E+02
Sb124		4.09E+02
Sb125		1.21E+03
Sb126		4.76E+02
Sb126m		7.93E+04
Sc-46		8.49E+02
Se 79		7.24E+02
Sm146		1.28E+02
Sm147		1.41E+02
Sm148		—
Sm149		—
Sm151		9.51E+03
Sn117m		1.21E+03
Sn119m		2.39E+03
Sn121m		2.26E+03
Sn123		3.77E+02
Sn125		2.63E+02
Sn126		2.06E+02
Sr89		4.12E+02
Sr90		9.45E+01
Tb160		6.07E+02

Table C-6. (continued).

Chemical	Residential Exposure Scenario	Individual RBC (mg/L)
Tb161		1.11E+03
Tc 98		7.44E+02
Tc 99		1.92E+03
Te123		1.28E+03
Te123m		1.28E+03
Te125m		1.59E+03
Te127		5.28E+03
Te127m		6.13E+02
Te129		3.09E+04
Te129m		3.45E+02
Th226		7.93E+03
Th227		1.11E+02
Th228		4.93E+01
Th229		2.36E+01
Th230		5.80E+01
Th231		2.39E+03
Th232		5.23E+01
Th234		2.29E+02
Tl207		—
Tl208		—
Tl209		—
Tm170		5.92E+02
Tm171		7.55E+03
U230		2.53E+01
U232		1.81E+01
U233		7.35E+01
U234		7.47E+01
U235		7.59E+01
U236		7.88E+01
U237		1.08E+03
U238		8.25E+01
U240		7.51E+02
Xe127		—
Xe129m		—

Table C-6. (continued).

Chemical	Residential Exposure Scenario	
		Individual RBC (mg/L)
Xe131m		—
Xe133		—
Y90		2.92E+02
Y91		3.30E+02
Zn65		4.51E+02
Zr93		4.76E+03
Zr95		1.15E+03

431.02  
01/30/2003  
Rev. 11

**ENGINEERING DESIGN FILE**

EDF-ER-275  
Revision 3  
Page 114 of 228

This page intentionally left blank.

## **Appendix D**

### **Effects of Recharge Rate Change on Remedial Action Objectives**

431.02  
01/30/2003  
Rev. 11

**ENGINEERING DESIGN FILE**

EDF-ER-275  
Revision 3  
Page 116 of 228

This page intentionally left blank.

## Appendix D

### Effects of Recharge Rate Change on Remedial Action Objectives

#### D.1 Cumulative Hazard Index Reduction by Design Cover, Design Life of 1,000 years.

The following provide a comparison of the various components of the remedial action objects based on modifications in the recharge rate from 0.01 m/year, the natural recharge rate, and 0.0001 m/year, the design recharge rate. The graphs are based on the design inventory concentrations of the waste soil as they are modeled to groundwater.

- Cumulative hazard index (HI) for the two recharge rates is provided in Figures D-1 and D-2
- Cumulative Excess Lifetime Cancer Risk is provided in Figures D-3 and D-4
- Reduction in total alpha emitters is provided in Figures D-5 and D-6.

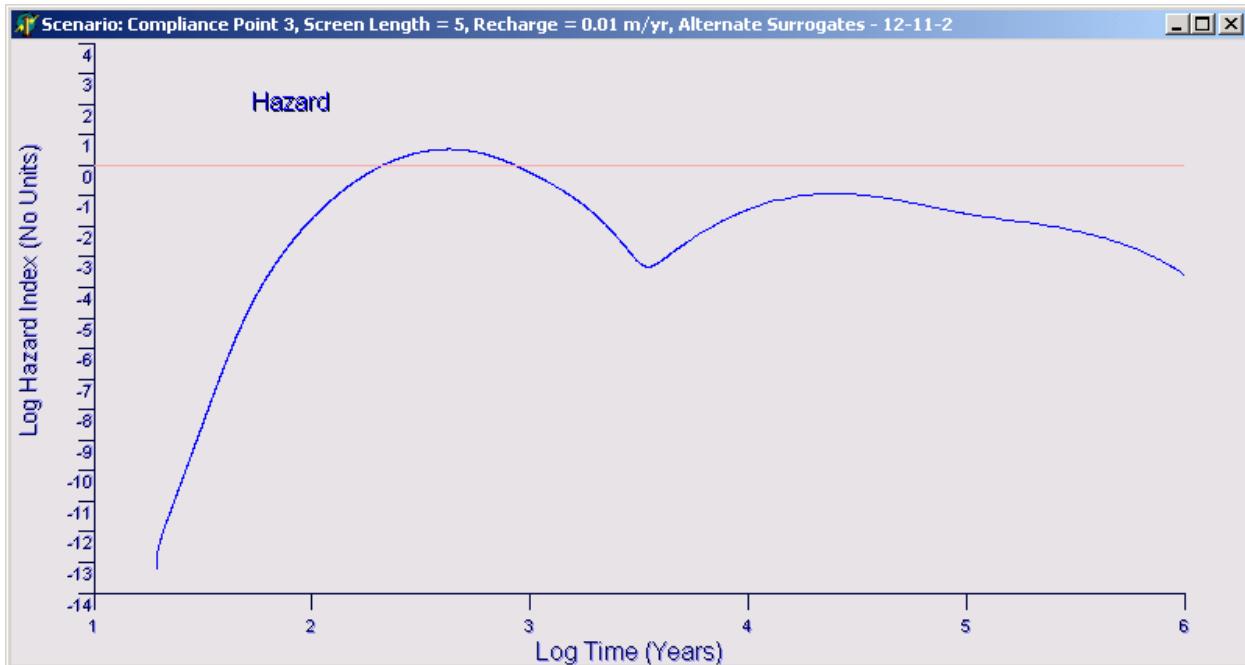


Figure D-1. Cumulative HI at background recharge of 0.01 m/yr.

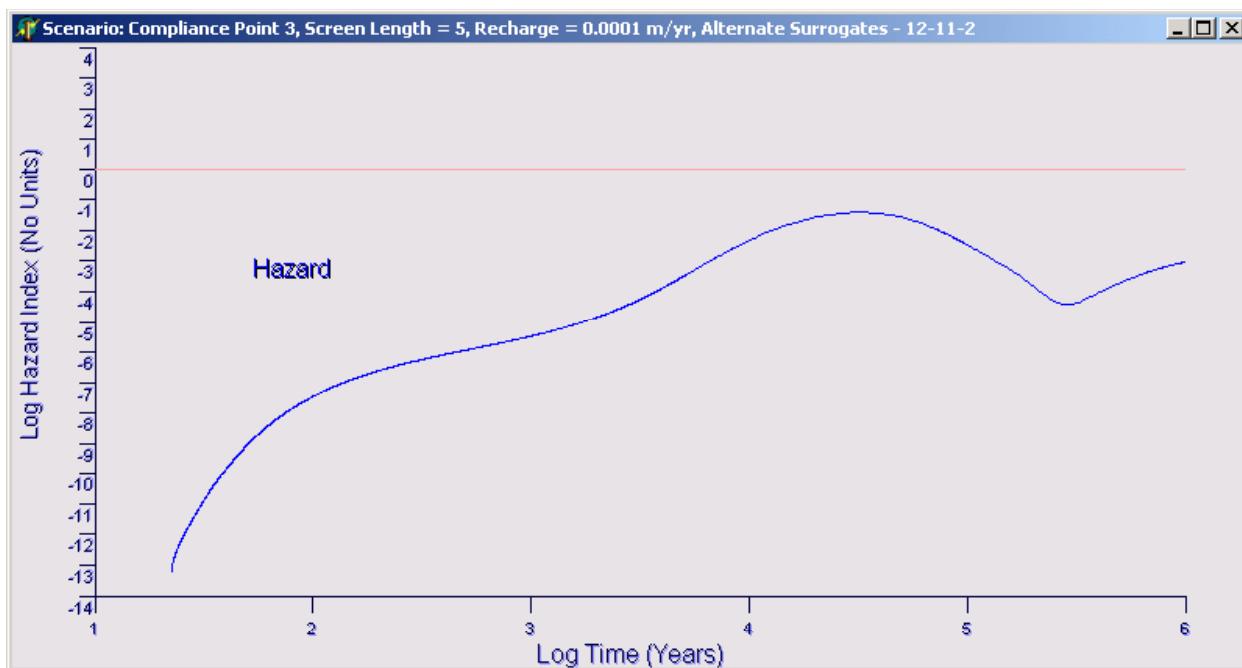


Figure D-2. Cumulative HI at cover recharge rate of 0.0001 m/yr.

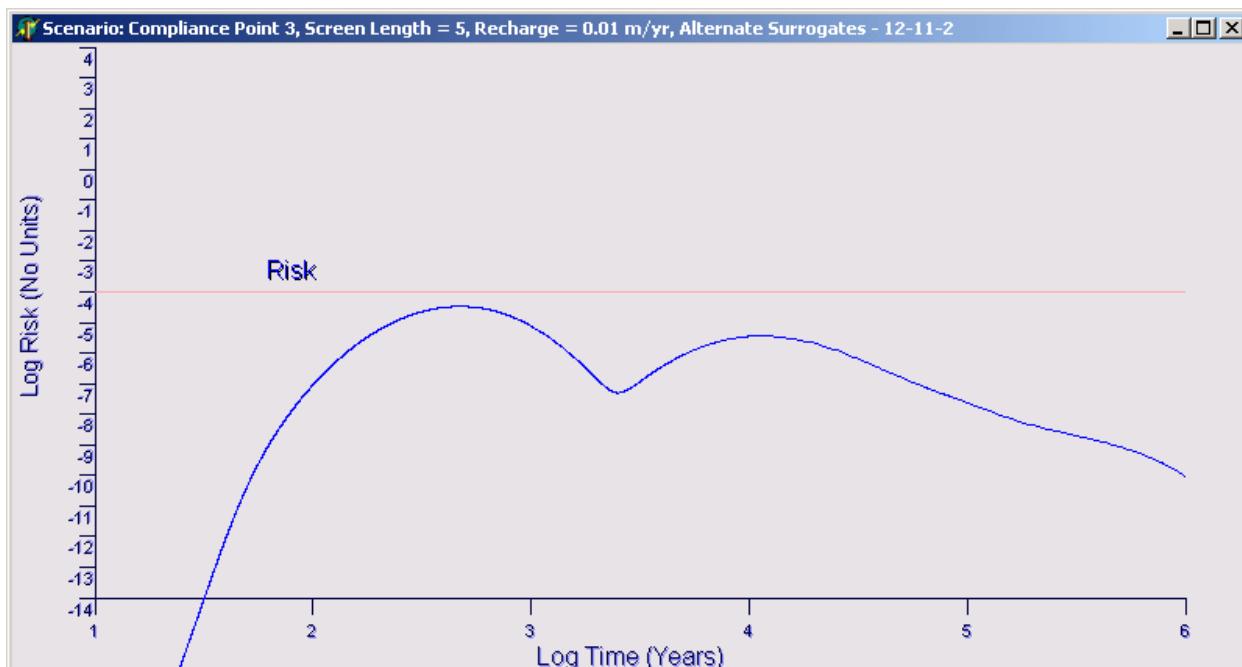


Figure D-3. Cumulative excess lifetime carcinogenic risk at background recharge of 0.01 m/yr.

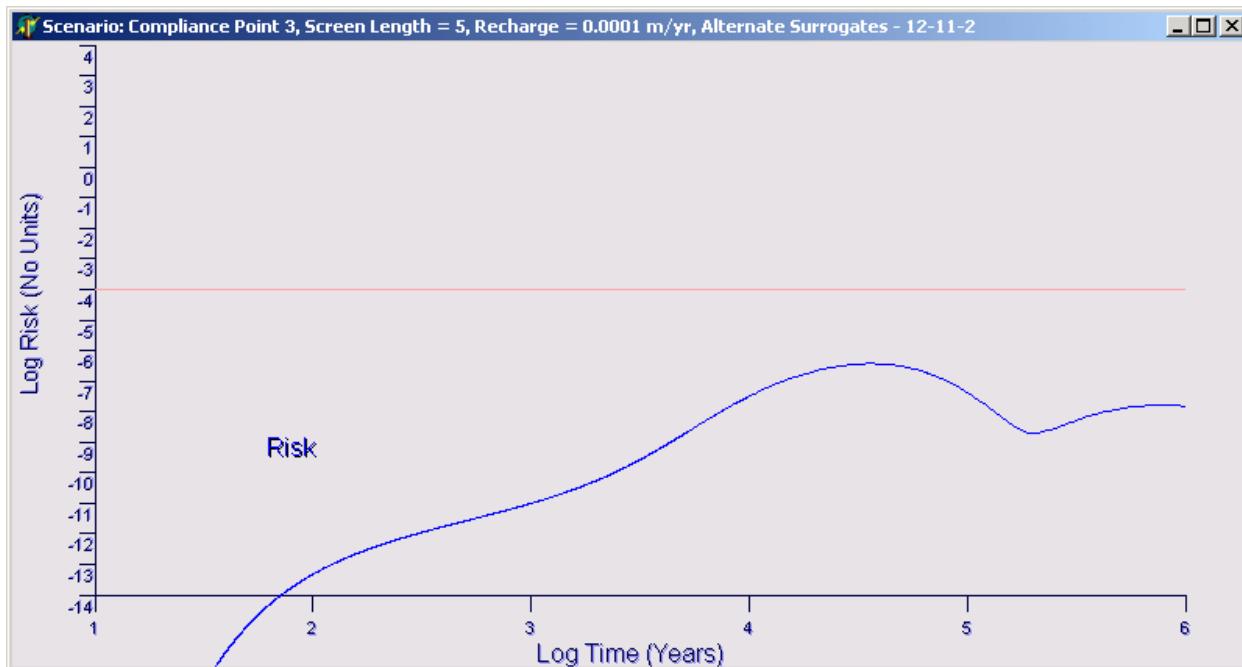


Figure D-4. Cumulative excess carcinogenic risk at design cover recharge rate of 0.0001 m/yr.

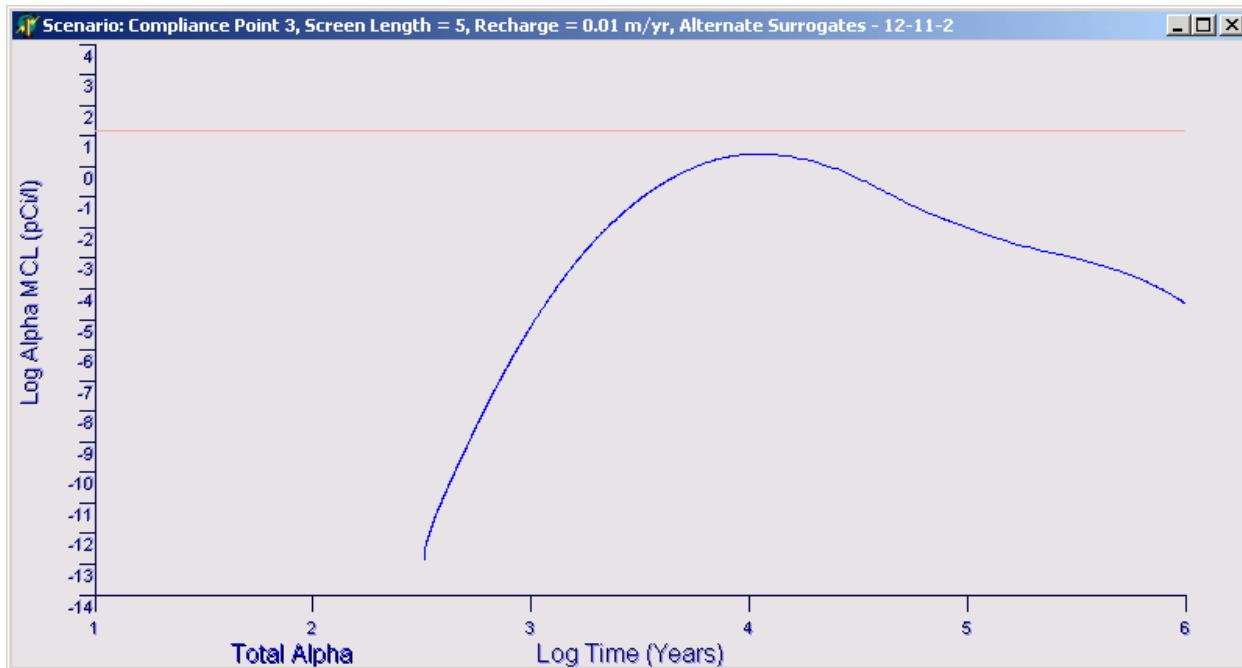


Figure D-5. Total alpha emitter concentration at background recharge rate of 0.01 m/yr.

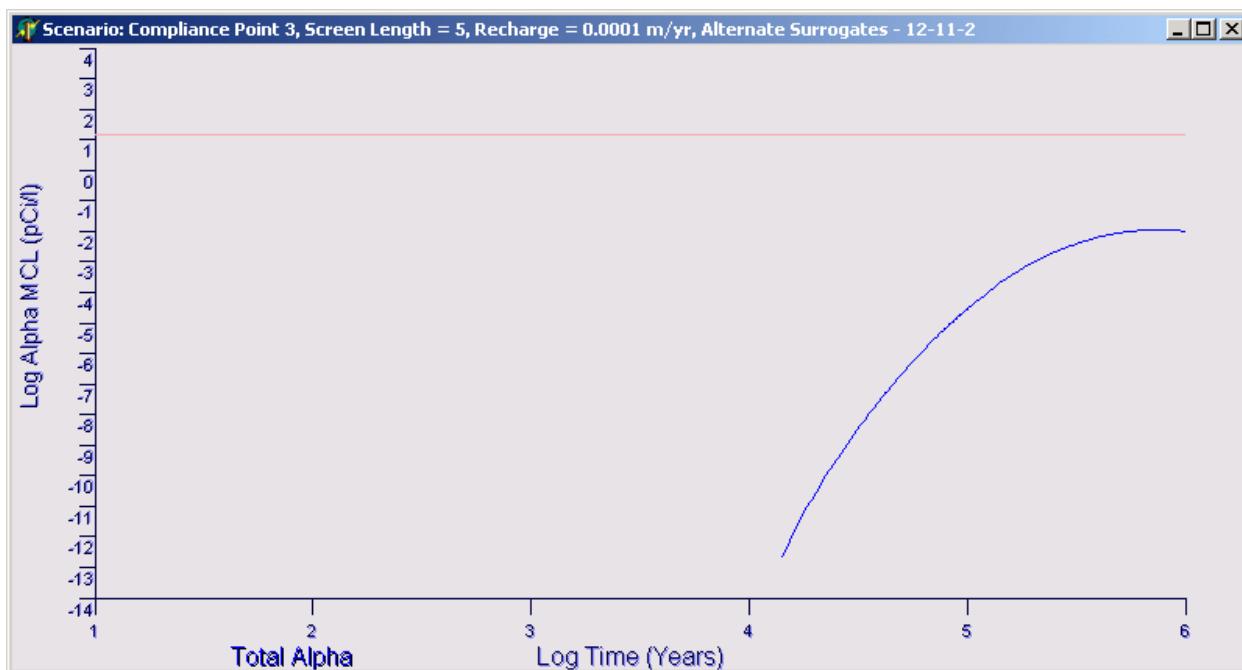


Figure D-6. Total alpha emitter concentration at design cover recharge rate of 0.0001 m/yr.

431.02  
01/30/2003  
Rev. 11

## **ENGINEERING DESIGN FILE**

EDF-ER-275  
Revision 3  
Page 121 of 228

### **Appendix E**

### **STOMP Input Files**

431.02  
01/30/2003  
Rev. 11

**ENGINEERING DESIGN FILE**

EDF-ER-275  
Revision 3  
Page 122 of 228

This page intentionally left blank.

## E.1. STEADY STATE INPUT

~Simulation Title Card  
1,  
B Pond Lengthwise Cross Section,  
WJ McMahon,  
CH2M Hill Hanford,  
August 17 2001,  
10:00 AM PDT,  
3,  
This input file is the contaminant transport run for the INEEL ICDF simulation  
This construction uses the geology developed by Pete Martian  
The input parameters are based on PM reports

~Solution Control Card  
normal,  
Water,  
1,  
0,day,500000,yr,6,s,50000,yr,1.25,8,1.e-6,  
3000,  
0,  
  
~Grid Card  
cartesian,  
60,1,98,  
# X Dimensions::160 m ICDF cell Total X Dimension 320 m  
0.,m,6@15,m,5@10,m,2@5,m,2@5,m,  
#20 m to screening model compliance point,  
2@5,m,1@4.,m,1@3.,m,1@2.,m,1@1.,m,  
#190 feet (or 58 m) to edge of landfill cap (less 20 m above)  
2@2.,m,1@3,m,1@4.,m,2@6.,m,1@4.,m,2@3.,m,2@2,m,1@1.,m,  
#190 feet (or 58 m) plus 20 m (less 58 m above)  
2@2.,m,1@3,m,1@4.,m,2@3.,m,1@2,m,1@1.,m,  
#190 feet (or 58 m) plus 100 m (less 78 m above)  
2@2.,m,1@3,m,2@4.,m,2@5.,m,5@8.,m,1@5.,m,1@4.,m,1@3.,m,1@2,m,1@1.,m,  
#One grid block to move last observation point off of boundary  
2@1.,m,  
# Y Dimensions (Y dimension not used)  
0.,m,1.,m,  
# Z Dimensions  
#Basalt Aquifer (Total = 76 m, Begin and End Lower 61 m) 9 Rows (Ignore 0)  
0.,m,2@12.,m,2@8.,m,2@6.,m,1@4.,m,1@3.,m,1@2.,m,  
#Basalt Aquifer Begin First 9 m of Upper 15 m 6 Rows  
6@1.5,m,  
#Basalt Aquifer Begin and End Upper 6 m  
# (7 m or 22 ft-note 6 m saturated and 1 m above water table) 6 Rows  
1@1,m,1@1,m,1@1,m,1@1,m,1@2,m,  
#Basalt (16.98 m or 57 ft-note that 1 m added to aquifer layer, 17.98 m = 59 ft)  
# 7 Rows  
1@2,m,1@2.32,m,1@2.75,m,1@3.25,m,1@3,m,1@2.15,m,1@1.51,m,  
#Sedimentary Interbed (7.01 m or 23 ft) 4 Rows  
1@1.51,m,1@2,m,1@2,m,1@1.5,m,  
#Basalt (39.93 m or 131 ft) 13 Rows  
1@1.5,m,1@2,m,1@3,m,1@4,m,1@4,m,1@4.5,m,1@4.5,m,1@4,m,1@4,m,1@3,m,1@2.4,m,

1@1.81,m,1@1.22,m,  
#Sedimentary Interbed (4.88 m or 16 ft) 4 Rows  
1@1.22,m,1@1.22,m,1@1.22,m,1@1.22,m,  
#Basalt (23.47 m or 77 ft) 9 Rows  
1@1.22,m,1@2,m,1@3,m,1@3.5,m,1@3.75,m,1@3.5,m,1@3,m,1@2,m,1@1.5,m,  
#Sedimentary Interbed (11.89 m or 39 ft) 6 Rows  
1@1.5,m,1@1.94,m,1@2.45,m,1@2.45,m,1@2.15,m,1@1.4,m,  
#Basalt (26.52 m or 87 ft) 13 Rows  
1@1.4,m,1@2,m,1@2,m,1@3,m,1@5,m,1@3,m,1@1.57,m,1@1.2,m,1@1,m,1@0.6,m,  
1@0.45,m,1@0.3,m,  
#Alluvium changed from 9 to 5 feet (1.52 m or 5 ft) 4 Rows  
1@0.30,m,1@0.46,m,1@0.46,m,1@0.30,m,  
#Clay Liner (0.91 m or 3 ft) 3 Rows  
1@0.30,m,1@0.31,m,1@0.30,m,  
#Operations Layer (0.91 m or 3 ft) 3 Rows  
1@0.30,m,1@0.31,m,1@0.30,m,  
#Waste (10.40 m or 34 ft adjusted to 12.56 m to account for cube vs  
trapezoid)  
# 11 Rows  
1@0.5,m,1@0.5,m,1@1,m,1@1,m,1@1.64,m,1@1.64,m,1@1.64,m,1@1.64,m,1@1,m,1@1,m,1  
@1,m,

~Rock/Soil Zonation Card

14,  
#Lower 61 m of Basalt Aquifer  
Basalt Aquifer,1,60,1,1,1,9,  
#Begin First 9 m of Upper 15 m of Basalt Aquifer  
Basalt Aquifer,1,60,1,1,10,15,  
#Upper 6 m of Basalt Aquifer  
Basalt Aquifer,1,60,1,1,16,21,  
#Lowest Vadose Basalt Layer  
Basalt,1,60,1,1,22,28,  
Interbed,1,60,1,1,29,32,  
Basalt,1,60,1,1,33,45,  
Interbed,1,60,1,1,46,49,  
Basalt,1,60,1,1,50,58,  
Interbed,1,60,1,1,59,64,  
Basalt,1,60,1,1,65,77,  
Alluvium,1,60,1,1,78,81,  
Clay,1,60,1,1,82,84,  
Operation Gravelly Sand,1,60,1,1,85,87,  
Waste Gravelly Sand,1,60,1,1,88,98,

~Inactive Nodes Card

#Integer,  
1,  
16,60,1,1,22,98,

~Mechanical Properties Card

#Particle density = 2650 kg/m^3 except for clay and old alluvium  
#Subgrade, attenuation barrier, and drain rock used in earlier models but  
#not used here  
#Basalt and interbed properties from P. Martian Screening Model  
Basalt Aquifer,,,0.06,0.06,,,Millington and Quirk,  
Interbed,,,0.487,0.487,,,Millington and Quirk,  
Basalt,,,0.05,0.05,,,Millington and Quirk,  
#

```
#Old Alluvium characteristics from Geotech report measurements
# sat. moisture content (0.422, 0.426); dry bulk density (1.60, 1.64 g/cm^3)
# particle density = 1.62 g/cm^3/(1-0.424) = 2.8125 g/cm^3
Alluvium,2812.5,kg/m^3,0.424,0.424,,,Millington and Quirk,
#Attenuation Barrier,,,0.400,0.400,,,Millington and Quirk,
#Clay characteristics per discussion with J. Dehner
Clay,2600,kg/m^3,0.390,0.390,,,Millington and Quirk,
#Drain Rock,,,0.400,0.400,,,Millington and Quirk,
Operation Gravelly Sand,,,0.275,0.275,,,Millington and Quirk,
#Operation Gravelly Sand dry bulk density = 120 lb/ft^3 (per J. Dehner)
#120 lb/ft^3*0.4536 kg/lb*1 ft^3/(0.3048 m/ft)^3 = 1922.25 kg/m^3
#Porosity Operation Gravelly Sand = 1-(1922.25/2650)= 0.275
Waste Gravelly Sand,,,0.266,0.266,,,Millington and Quirk,
#Waste Gravelly Sand dry bulk density = 121.5 lb/ft^3 (per J. Dehner)
#121.5 lb/ft^3*0.4536 kg/lb*1 ft^3/(0.3048 m)^3 = 1946.28 kg/m^3
#Porosity Waste Gravelly Sand = 1-(1946.28/2650)= 0.266
```

~Hydraulic Properties Card

```
#Properties from P. Martian Screening Model except old alluvium
Basalt Aquifer,9.00e+01,darcy,,,3.00e-01,darcy,
Interbed,6.7e-5,hc:cm/s,,,6.7e-5,hc:cm/s,
Basalt,9.00e+01,darcy,,,3.00e-01,darcy,
#Old Alluvium characteristics from Geotech report measurements
# sat. hydraulic conductivity (1.2e-07 cm/s, 6.2e-08 cm/s, 7.1e-08 cm/s)
Alluvium,1.2e-07,hc:cm/s,,,1.2e-07,hc:cm/s,
#Subgrade,1e-04,hc:cm/s,,,1e-04,hc:cm/s,
#Attenuation Barrier,1e-07,hc:cm/s,,,1e-07,hc:cm/s,
Clay,1e-07,hc:cm/s,,,1e-07,hc:cm/s,
#Drain Rock,3.0e-01,hc:cm/s,,,3.0e-01,hc:cm/s,
Operation Gravelly Sand,1e-04,hc:cm/s,,,1e-04,hc:cm/s,
Waste Gravelly Sand,1e-03,hc:cm/s,,,1e-03,hc:cm/s,
```

~Saturation Function Card

```
#Parameters from P. Martian Screening Model except old alluvium
#alpha, n, theta R, m
#m only specified for basalts, otherwise default m = 1 - 1/n
Basalt Aquifer,Nonhysteretic van Genuchten,4.0,1/m,4.5,0.0002,0.7777778,
Interbed,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.142,,,
Basalt,Nonhysteretic van Genuchten,4.0,1/m,4.5,0.0002,0.7777778,
#Old Alluvium characteristics from RETC fitting of Geotech report
measurements
Alluvium,Nonhysteretic van Genuchten,0.595,1/m,1.108,0.142,,,
#Subgrade,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.142,,,
#Attenuation Barrier,Nonhysteretic van Genuchten,0.800,1/m,1.090,0.07,,,
Clay,Nonhysteretic van Genuchten,0.800,1/m,1.09,0.07,,,
#Drain Rock,Nonhysteretic van Genuchten,493,1/m,2.190,0.005,,,
Operation Gravelly Sand,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.083,,,
Waste Gravelly Sand,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.072,,,
#
```

~Aqueous Relative Permeability Card

```
#m only specified for basalts, otherwise default m = 1 - 1/n
Basalt Aquifer,Mualem,1.9,
Interbed,Mualem,,,
Basalt,Mualem,1.9,
Alluvium,Mualem,,,
#Subgrade,Mualem,,
```

```
#Attenuation Barrier,Mualem,,  
Clay,Mualem,,  
#Drain Rock,Mualem,,  
Operation Gravelly Sand,Mualem,,  
Waste Gravelly Sand,Mualem,,  
#  
  
~Initial Conditions Card  
Gas Pressure,Aqueous Pressure,  
1,  
Aqueous Pressure,789004.67,Pa,-6.67,1/m,,, -9793.52,1/m,1,60,1,1,1,1,98,  
#  
  
~Boundary Conditions Card  
4,  
#  
#recharge at top = 1 cm/yr [negative specifies downward]  
top,neumann,  
1,15,1,1,98,98,1,  
0,day,-1.00,cm/yr,  
#  
#Flow in from the side: v = 1 m/d thus Q = 0.06 m/d  
west,neumann,  
1,1,1,1,1,20,1,  
0,day,0.06,m/day,  
#  
west,neumann,  
#Cell only partly saturated (1 m/2 m) thus Q = 0.03 m/d * (1/2)  
1,1,1,1,21,21,1,  
0,day,0.03,m/day,  
#  
east,hydraulic gradient,  
#Hold head constant to keep h ~ 5 m at compliance point  
60,60,1,1,1,21,1,  
0,day,786871.34,Pa,  
#  
  
~Surface Flux Card  
3,  
#check for mass balance  
Aqueous Volumetric Flux,m^3/yr,m^3,west,1,1,1,1,1,21,  
Aqueous Volumetric Flux,m^3/yr,m^3,east,60,60,1,1,1,21,  
Aqueous Volumetric Flux,m^3/yr,m^3,top,1,15,1,1,81,81,  
  
~Output Control Card  
4,  
15,1,88,  
15,1,21,  
59,1,21,  
59,1,15,  
1,1,yr,m,8,8,8,  
4,  
aqueous saturation,,  
aqueous pressure,Pa,  
aqueous moisture content,,  
znc aqueous vol,m/yr,  
2,
```

431.02  
01/30/2003  
Rev. 11

## ENGINEERING DESIGN FILE

EDF-ER-275  
Revision 3  
Page 127 of 228

0, yr,  
10000, yr,  
5,  
aqueous saturation,,  
aqueous pressure, Pa,  
aqueous moisture content,,  
znc aqueous vol, m/yr,  
rock/soil type,,

## E.2. Natural Recharge, Surrogates 1-4 Input

~Simulation Title Card

1,  
B Pond Lengthwise Cross Section,  
WJ McMahon,  
CH2M Hill Hanford,  
July 23 2001,  
10:00 AM PDT,  
3,  
This input file is the contaminant transport run for the INEEL ICDF simulation  
This construction uses the geology developed by Pete Martian  
The input parameters are based on PM reports

~Solution Control Card

Restart,restart,  
Water w/ Solute Transport,  
9,  
0,day,20,yr,0.0007,yr,0.02,yr,1.25,8,1.e-6,  
20,yr,50,yr,0.02,yr,0.05,yr,1.25,8,1.e-6,  
50,yr,100,yr,0.05,yr,0.10,yr,1.25,8,1.e-6,  
100,yr,500,yr,0.10,yr,0.50,yr,1.25,8,1.e-6,  
500,yr,1000,yr,0.50,yr,2,yr,1.25,8,1.e-6,  
1000,yr,5000,yr,2,yr,10,yr,1.25,8,1.e-6,  
5000,yr,10000,yr,10,yr,100,yr,1.25,8,1.e-6,  
10000,yr,100000,yr,100,yr,1000,yr,1.25,8,1.e-6,  
100000,yr,1000000,yr,1000,yr,10000,yr,1.25,8,1.e-6,  
8000,  
0,

~Grid Card

cartesian,  
60,1,98,  
# X Dimensions::160 m ICDF cell Total X Dimension 320 m  
0.,m,6@15,m,5@10,m,2@5,m,2@5,m,  
#20 m to screening model compliance point,  
2@5,m,1@4.,m,1@3.,m,1@2.,m,1@1.,m,  
#190 feet (or 58 m) to edge of landfill cap (less 20 m above)  
2@2.,m,1@3,m,1@4.,m,2@6.,m,1@4.,m,2@3.,m,2@2,m,1@1.,m,  
#190 feet (or 58 m) plus 20 m (less 58 m above)  
2@2.,m,1@3,m,1@4.,m,2@3.,m,1@2,m,1@1.,m,  
#190 feet (or 58 m) plus 100 m (less 78 m above)  
2@2.,m,1@3,m,2@4.,m,2@5.,m,5@8.,m,1@5.,m,1@4.,m,1@3.,m,1@2,m,1@1.,m,  
#One grid block to move last observation point off of boundary  
2@1.,m,  
# Y Dimensions (Y dimension not used)  
0.,m,1.,m,  
# Z Dimensions  
#Basalt Aquifer (Total = 76 m, Begin and End Lower 61 m) 9 Rows (Ignore 0)  
0.,m,2@12.,m,2@8.,m,2@6.,m,1@4.,m,1@3.,m,1@2.,m,  
#Basalt Aquifer Begin First 9 m of Upper 15 m 6 Rows  
6@1.5,m,  
#Basalt Aquifer Begin and End Upper 6 m  
# (7 m or 22 ft-note 6 m saturated and 1 m above water table) 6 Rows  
1@1,m,1@1,m,1@1,m,1@1,m,1@1,m,1@2,m,

```
#Basalt (16.98 m or 57 ft-note that 1 m added to aquifer layer, 17.98 m = 59
ft)
# 7 Rows
1@2,m,1@2.32,m,1@2.75,m,1@3.25,m,1@3,m,1@2.15,m,1@1.51,m,
#Sedimentary Interbed (7.01 m or 23 ft) 4 Rows
1@1.51,m,1@2,m,1@2,m,1@1.5,m,
#Basalt (39.93 m or 131 ft) 13 Rows
1@1.5,m,1@2,m,1@3,m,1@4,m,1@4,m,1@4.5,m,1@4.5,m,1@4,m,1@3,m,1@2.4,m,
1@1.81,m,1@1.22,m,
#Sedimentary Interbed (4.88 m or 16 ft) 4 Rows
1@1.22,m,1@1.22,m,1@1.22,m,1@1.22,m,
#Basalt (23.47 m or 77 ft) 9 Rows
1@1.22,m,1@2,m,1@3,m,1@3.5,m,1@3.75,m,1@3.5,m,1@3,m,1@2,m,1@1.5,m,
#Sedimentary Interbed (11.89 m or 39 ft) 6 Rows
1@1.5,m,1@1.94,m,1@2.45,m,1@2.45,m,1@2.15,m,1@1.4,m,
#Basalt (26.52 m or 87 ft) 13 Rows
1@1.4,m,1@2,m,1@2,m,1@3,m,1@5,m,1@5,m,1@3,m,1@1.57,m,1@1.2,m,1@1,m,1@0.6,m,
1@0.45,m,1@0.3,m,
#Alluvium changed from 9 to 5 feet (1.52 m or 5 ft) 4 Rows
1@0.30,m,1@0.46,m,1@0.46,m,1@0.30,m,
#Clay Liner (0.91 m or 3 ft) 3 Rows
1@0.30,m,1@0.31,m,1@0.30,m,
#Operations Layer (0.91 m or 3 ft) 3 Rows
1@0.30,m,1@0.31,m,1@0.30,m,
#Waste (10.40 m or 34 ft adjusted to 12.56 m to account for cube vs
trapezoid)
# 11 Rows
1@0.5,m,1@0.5,m,1@1,m,1@1,m,1@1.64,m,1@1.64,m,1@1.64,m,1@1.64,m,1@1,m,1@1,m,1
@1,m,
```

~Rock/Soil Zonation Card

```
14,
#Lower 61 m of Basalt Aquifer
Basalt Aquifer,1,60,1,1,1,9,
#Begin First 9 m of Upper 15 m of Basalt Aquifer
Basalt Aquifer,1,60,1,1,10,15,
#Upper 6 m of Basalt Aquifer
Basalt Aquifer,1,60,1,1,16,21,
#Lowest Vadose Basalt Layer
Basalt,1,60,1,1,22,28,
Interbed,1,60,1,1,29,32,
Basalt,1,60,1,1,33,45,
Interbed,1,60,1,1,46,49,
Basalt,1,60,1,1,50,58,
Interbed,1,60,1,1,59,64,
Basalt,1,60,1,1,65,77,
Alluvium,1,60,1,1,78,81,
Clay,1,60,1,1,82,84,
Operation Gravelly Sand,1,60,1,1,85,87,
Waste Gravelly Sand,1,60,1,1,88,98,
```

~Inactive Nodes Card

```
#Integer,
1,
16,60,1,1,22,98,
```

~Mechanical Properties Card

```
#Particle density = 2650 kg/m^3 except for clay and old alluvium
#Subgrade, attenuation barrier, and drain rock used in earlier models but
#not used here
#Basalt and interbed properties from P. Martian Screening Model
Basalt Aquifer,,,0.06,0.06,,,Millington and Quirk,
Interbed,,,0.487,0.487,,,Millington and Quirk,
Basalt,,,0.05,0.05,,,Millington and Quirk,
#
#Old Alluvium characteristics from Geotech report measurements
# sat. moisture content (0.422, 0.426); dry bulk density (1.60, 1.64 g/cm^3)
# particle density = 1.62 g/cm^3/(1-0.424) = 2.8125 g/cm^3
Alluvium,2812.5,kg/m^3,0.424,0.424,,,Millington and Quirk,
#Attenuation Barrier,,,0.400,0.400,,,Millington and Quirk,
#Clay characteristics per discussion with J. Dehner
Clay,2600,kg/m^3,0.390,0.390,,,Millington and Quirk,
#Drain Rock,,,0.400,0.400,,,Millington and Quirk,
Operation Gravelly Sand,,,0.275,0.275,,,Millington and Quirk,
#Operation Gravelly Sand dry bulk density = 120 lb/ft^3 (per J. Dehner)
#120 lb/ft^3*0.4536 kg/lb*1 ft^3/(0.3048 m/ft)^3 = 1922.25 kg/m^3
#Porosity Operation Gravelly Sand = 1-(1922.25/2650)= 0.275
Waste Gravelly Sand,,,0.266,0.266,,,Millington and Quirk,
#Waste Gravelly Sand dry bulk density = 121.5 lb/ft^3 (per J. Dehner)
#121.5 lb/ft^3*0.4536 kg/lb*1 ft^3/(0.3048 m)^3 = 1946.28 kg/m^3
#Porosity Waste Gravelly Sand = 1-(1946.28/2650)= 0.266
```

```
~Hydraulic Properties Card
#Properties from P. Martian Screening Model except old alluvium
Basalt Aquifer,9.00e+01,darcy,,,3.00e-01,darcy,
Interbed,6.7e-5,hc:cm/s,,,6.7e-5,hc:cm/s,
Basalt,9.00e+01,darcy,,,3.00e-01,darcy,
#Old Alluvium characteristics from Geotech report measurements
# sat. hydraulic conductivity (1.2e-07 cm/s, 6.2e-08 cm/s, 7.1e-08 cm/s)
Alluvium,1.2e-07,hc:cm/s,,,1.2e-07,hc:cm/s,
#Subgrade,1e-04,hc:cm/s,,,1e-04,hc:cm/s,
#Attenuation Barrier,1e-07,hc:cm/s,,,1e-07,hc:cm/s,
Clay,1e-07,hc:cm/s,,,1e-07,hc:cm/s,
#Drain Rock,3.0e-01,hc:cm/s,,,3.0e-01,hc:cm/s,
Operation Gravelly Sand,1e-04,hc:cm/s,,,1e-04,hc:cm/s,
Waste Gravelly Sand,1e-03,hc:cm/s,,,1e-03,hc:cm/s,
```

```
~Saturation Function Card
#Parameters from P. Martian Screening Model except old alluvium
#alpha, n, theta R, m
#m only specified for basalts, otherwise default m = 1 - 1/n
Basalt Aquifer,Nonhysteretic van Genuchten,4.0,1/m,4.5,0.0002,0.7777778,
Interbed,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.142,,,
Basalt,Nonhysteretic van Genuchten,4.0,1/m,4.5,0.0002,0.7777778,
#Old Alluvium characteristics from RETC fitting of Geotech report
measurements
Alluvium,Nonhysteretic van Genuchten,0.595,1/m,1.09,0.142,,,
#Subgrade,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.142,,,
#Attenuation Barrier,Nonhysteretic van Genuchten,0.800,1/m,1.090,0.07,,,
Clay,Nonhysteretic van Genuchten,0.800,1/m,1.109,0.07,,,
#Drain Rock,Nonhysteretic van Genuchten,493,1/m,2.190,0.005,,,
Operation Gravelly Sand,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.083,,,
Waste Gravelly Sand,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.072,,,
#
```

```
~Aqueous Relative Permeability Card
#m only specified for basalts, otherwise default m = 1 - 1/n
Basalt Aquifer,Mualem,1.9,
Interbed,Mualem.,
Basalt,Mualem,1.9,
Alluvium,Mualem.,
#Subgrade,Mualem.,
#Attenuation Barrier,Mualem.,
Clay,Mualem.,
#Drain Rock,Mualem.,
Operation Gravelly Sand,Mualem.,
Waste Gravelly Sand,Mualem.,
#
~Solute/Fluid Interactions Card
4,
H-3,conventional,1.0e-09,m^2/s,noncontinuous,,,,
I-129,conventional,1.0e-09,m^2/s,noncontinuous,,,,
Tc-99,conventional,1.0e-09,m^2/s,noncontinuous,,,,
U-235,conventional,1.0e-09,m^2/s,noncontinuous,,,,
#Np-237,conventional,1.0e-09,m^2/s,noncontinuous,,,,
#Sr-90,conventional,1.0e-09,m^2/s,noncontinuous,,,,
#Zn-65,conventional,1.0e-09,m^2/s,noncontinuous,,,,
#Eu-155,conventional,1.0e-09,m^2/s,noncontinuous,,,,
0,
#
~Solute/Porous Media Interaction Card
Basalt Aquifer,6.0,m,3.0,m,
H-3,0.0,cm^3/g,
I-129,0.0,cm^3/g,
Tc-99,0.008,cm^3/g,
U-235,0.24,cm^3/g,
#Np-237,0.32,cm^3/g,
#Sr-90,0.48,cm^3/g,
#Zn-65,0.64,cm^3/g,
#Eu-155,314,cm^3/g,
#
Interbed,5.0,m,0,m,
H-3,0.0,cm^3/g,
I-129,0.0,cm^3/g,
Tc-99,0.2,cm^3/g,
U-235,6.0,cm^3/g,
#Np-237,8.0,cm^3/g,
#Sr-90,24.0,cm^3/g,
#Zn-65,16.0,cm^3/g,
#Eu-155,314,cm^3/g,
#
Basalt,5.0,m,0,m,
H-3,0.0,cm^3/g,
I-129,0.0,cm^3/g,
Tc-99,0.0,cm^3/g,
U-235,0.0,cm^3/g,
#Np-237,0.0,cm^3/g,
#Sr-90,0.0,cm^3/g,
#Zn-65,0.0,cm^3/g,
#Eu-155,314,cm^3/g,
#
#Subgrade,5.0,m,0,m,
```

```
#  
Alluvium,5.0,m,0,m,  
H-3,0.0,cm^3/g,  
I-129,0.0,cm^3/g,  
Tc-99,0.2,cm^3/g,  
U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,  
#Sr-90,24.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
#Eu-155,314,cm^3/g,  
#  
#Attenuation Barrier,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
#I-129,1.0,cm^3/g,  
#Tc-99,1.0,cm^3/g,  
#U-235,63.0,cm^3/g,  
#Np-237,55.0,cm^3/g,  
#Sr-90,200.0,cm^3/g,  
#Zn-65,2400.0,cm^3/g,  
#Eu-155,314,cm^3/g,  
#  
Clay,5.0,m,0,m,  
H-3,0.0,cm^3/g,  
I-129,1.0,cm^3/g,  
Tc-99,1.0,cm^3/g,  
U-235,63.0,cm^3/g,  
#Np-237,55.0,cm^3/g,  
#Sr-90,200.0,cm^3/g,  
#Zn-65,2400.0,cm^3/g,  
#Eu-155,314,cm^3/g,  
#  
#Drain Rock,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
#I-129,0.0,cm^3/g,  
#Tc-99,0.2,cm^3/g,  
#U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,  
#Sr-90,24.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
#Eu-155,314,cm^3/g,  
#  
Operation Gravelly Sand,5.0,m,0,m,  
H-3,0.0,cm^3/g,  
I-129,0.0,cm^3/g,  
Tc-99,0.2,cm^3/g,  
U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,  
#Sr-90,24.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
#Eu-155,314,cm^3/g,  
#  
Waste Gravelly Sand,5.0,m,0,m,  
H-3,0.0,cm^3/g,  
I-129,0.0,cm^3/g,  
Tc-99,0.2,cm^3/g,  
U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,
```

```
#Sr-90,12.0,cm^3/g,
#Zn-65,16.0,cm^3/g,
#Eu-155,314,cm^3/g,
#
~Initial Conditions Card
Gas Pressure,Aqueous Pressure,
9,
Aqueous Pressure,,,,,,,1,60,1,1,1,98,
Solute Volume Overwrite,H-3,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,
Solute Volume Overwrite,I-129,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,
Solute Volume Overwrite,Tc-99,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,
Solute Volume Overwrite,U-235,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,
#Solute Volume Overwrite,Np-237,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,
#Solute Volume Overwrite,Sr-90,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,
#Solute Volume Overwrite,Zn-65,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,
#Solute Volume Overwrite,Eu-155,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,
#
Solute Volume Overwrite,H-3,1946.28,1/m^3,0,,0,,0,,1,15,1,1,88,98,
Solute Volume Overwrite,I-129,1946.28,1/m^3,0,,0,,0,,1,15,1,1,88,98,
Solute Volume Overwrite,Tc-99,1946.28,1/m^3,0,,0,,0,,1,15,1,1,88,98,
Solute Volume Overwrite,U-235,1946.28,1/m^3,0,,0,,0,,1,15,1,1,88,98,
#Solute Volume Overwrite,Np-237,1946.28,1/m^3,0,,0,,0,,1,15,1,1,88,98,
#Solute Volume Overwrite,Sr-90,1946.28,1/m^3,0,,0,,0,,1,15,1,1,88,98,
#Solute Volume Overwrite,Zn-65,1946.28,1/m^3,0,,0,,0,,1,15,1,1,88,98,
#Solute Volume Overwrite,Eu-155,1946.28,1/m^3,0,,0,,0,,1,15,1,1,88,98,

~Boundary Conditions Card
4,
#
top,neumann,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,
#0.01 m/yr * 1.74 ICDF Recharge Ratio = 0.0174 m/yr
1,15,1,1,98,98,1,
0,day,-0.0174,m/yr,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,
#0,1/m^3,0,1/m^3,
#0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,
#
west,neumann,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,
1,1,1,1,20,1,
0,day,0.06,m/day,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,
#0,1/m^3,0,1/m^3,
#0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,
#
west,neumann,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,
1,1,1,1,21,1,
0,day,0.03,m/day,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,
#0,1/m^3,0,1/m^3,
#0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,
#
east,hydraulic gradient,outflow,outflow,outflow,outflow,
#Hold head constant to keep h ~ 5 m at compliance point
60,60,1,1,1,21,1,
```

```
0,day,786871.34,Pa,,,,,,,,,,  
#  
~Surface Flux Card  
50,  
Aqueous Volumetric Flux,m^3/yr,m^3,bottom,1,15,1,1,82,82,  
Solute Flux,H-3,1/yr,,bottom,1,15,1,1,82,82,  
Solute Flux,I-129,1/yr,,bottom,1,15,1,1,82,82,  
Solute Flux,Tc-99,1/yr,,bottom,1,15,1,1,82,82,  
Solute Flux,U-235,1/yr,,bottom,1,15,1,1,82,82,  
#Solute Flux,Np-237,1/yr,,bottom,1,15,1,1,82,82,  
#Solute Flux,Sr-90,1/yr,,bottom,1,15,1,1,82,82,  
#Solute Flux,Zn-65,1/yr,,bottom,1,15,1,1,82,82,  
#Solute Flux,Eu-155,1/yr,,bottom,1,15,1,1,82,82,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,bottom,1,15,1,1,22,22,  
Solute Flux,H-3,1/yr,,bottom,1,15,1,1,22,22,  
Solute Flux,I-129,1/yr,,bottom,1,15,1,1,22,22,  
Solute Flux,Tc-99,1/yr,,bottom,1,15,1,1,22,22,  
Solute Flux,U-235,1/yr,,bottom,1,15,1,1,22,22,  
#Solute Flux,Np-237,1/yr,,bottom,1,15,1,1,22,22,  
#Solute Flux,Sr-90,1/yr,,bottom,1,15,1,1,22,22,  
#Solute Flux,Zn-65,1/yr,,bottom,1,15,1,1,22,22,  
#Solute Flux,Eu-155,1/yr,,bottom,1,15,1,1,22,22,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,21,21,1,1,10,21,  
Solute Flux,H-3,1/yr,,west,21,21,1,1,10,21,  
Solute Flux,I-129,1/yr,,west,21,21,1,1,10,21,  
Solute Flux,Tc-99,1/yr,,west,21,21,1,1,10,21,  
Solute Flux,U-235,1/yr,,west,21,21,1,1,10,21,  
#Solute Flux,Np-237,1/yr,,west,21,21,1,1,10,21,  
#Solute Flux,Sr-90,1/yr,,west,21,21,1,1,10,21,  
#Solute Flux,Zn-65,1/yr,,west,21,21,1,1,10,21,  
#Solute Flux,Eu-155,1/yr,,west,21,21,1,1,10,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,21,21,1,1,17,21,  
Solute Flux,H-3,1/yr,,west,21,21,1,1,17,21,  
Solute Flux,I-129,1/yr,,west,21,21,1,1,17,21,  
Solute Flux,Tc-99,1/yr,,west,21,21,1,1,17,21,  
Solute Flux,U-235,1/yr,,west,21,21,1,1,17,21,  
#Solute Flux,Np-237,1/yr,,west,21,21,1,1,17,21,  
#Solute Flux,Sr-90,1/yr,,west,21,21,1,1,17,21,  
#Solute Flux,Zn-65,1/yr,,west,21,21,1,1,17,21,  
#Solute Flux,Eu-155,1/yr,,west,21,21,1,1,17,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,33,33,1,1,10,21,  
Solute Flux,H-3,1/yr,,west,33,33,1,1,10,21,  
Solute Flux,I-129,1/yr,,west,33,33,1,1,10,21,  
Solute Flux,Tc-99,1/yr,,west,33,33,1,1,10,21,  
Solute Flux,U-235,1/yr,,west,33,33,1,1,10,21,  
#Solute Flux,Np-237,1/yr,,west,33,33,1,1,10,21,  
#Solute Flux,Sr-90,1/yr,,west,33,33,1,1,10,21,  
#Solute Flux,Zn-65,1/yr,,west,33,33,1,1,10,21,  
#Solute Flux,Eu-155,1/yr,,west,33,33,1,1,10,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,33,33,1,1,17,21,  
Solute Flux,H-3,1/yr,,west,33,33,1,1,17,21,  
Solute Flux,I-129,1/yr,,west,33,33,1,1,17,21,
```

```
Solute Flux,Tc-99,1/yr,,west,33,33,1,1,17,21,  
Solute Flux,U-235,1/yr,,west,33,33,1,1,17,21,  
#Solute Flux,Np-237,1/yr,,west,33,33,1,1,17,21,  
#Solute Flux,Sr-90,1/yr,,west,33,33,1,1,17,21,  
#Solute Flux,Zn-65,1/yr,,west,33,33,1,1,17,21,  
#Solute Flux,Eu-155,1/yr,,west,33,33,1,1,17,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,41,41,1,1,10,21,  
Solute Flux,H-3,1/yr,,west,41,41,1,1,10,21,  
Solute Flux,I-129,1/yr,,west,41,41,1,1,10,21,  
Solute Flux,Tc-99,1/yr,,west,41,41,1,1,10,21,  
Solute Flux,U-235,1/yr,,west,41,41,1,1,10,21,  
#Solute Flux,Np-237,1/yr,,west,41,41,1,1,10,21,  
#Solute Flux,Sr-90,1/yr,,west,41,41,1,1,10,21,  
#Solute Flux,Zn-65,1/yr,,west,41,41,1,1,10,21,  
#Solute Flux,Eu-155,1/yr,,west,41,41,1,1,10,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,41,41,1,1,17,21,  
Solute Flux,H-3,1/yr,,west,41,41,1,1,17,21,  
Solute Flux,I-129,1/yr,,west,41,41,1,1,17,21,  
Solute Flux,Tc-99,1/yr,,west,41,41,1,1,17,21,  
Solute Flux,U-235,1/yr,,west,41,41,1,1,17,21,  
#Solute Flux,Np-237,1/yr,,west,41,41,1,1,17,21,  
#Solute Flux,Sr-90,1/yr,,west,41,41,1,1,17,21,  
#Solute Flux,Zn-65,1/yr,,west,41,41,1,1,17,21,  
#Solute Flux,Eu-155,1/yr,,west,41,41,1,1,17,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,58,58,1,1,10,21,  
Solute Flux,H-3,1/yr,,west,58,58,1,1,10,21,  
Solute Flux,I-129,1/yr,,west,58,58,1,1,10,21,  
Solute Flux,Tc-99,1/yr,,west,58,58,1,1,10,21,  
Solute Flux,U-235,1/yr,,west,58,58,1,1,10,21,  
#Solute Flux,Np-237,1/yr,,west,58,58,1,1,10,21,  
#Solute Flux,Sr-90,1/yr,,west,58,58,1,1,10,21,  
#Solute Flux,Zn-65,1/yr,,west,58,58,1,1,10,21,  
#Solute Flux,Eu-155,1/yr,,west,58,58,1,1,10,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,58,58,1,1,17,21,  
Solute Flux,H-3,1/yr,,west,58,58,1,1,17,21,  
Solute Flux,I-129,1/yr,,west,58,58,1,1,17,21,  
Solute Flux,Tc-99,1/yr,,west,58,58,1,1,17,21,  
Solute Flux,U-235,1/yr,,west,58,58,1,1,17,21,  
#Solute Flux,Np-237,1/yr,,west,58,58,1,1,17,21,  
#Solute Flux,Sr-90,1/yr,,west,58,58,1,1,17,21,  
#Solute Flux,Zn-65,1/yr,,west,58,58,1,1,17,21,  
#Solute Flux,Eu-155,1/yr,,west,58,58,1,1,17,21,  
#  
~Output Control Card  
48,  
21,1,10,  
21,1,11,  
21,1,12,  
21,1,13,  
21,1,14,  
21,1,15,  
21,1,16,  
21,1,17,
```

21,1,18,  
21,1,19,  
21,1,20,  
21,1,21,  
33,1,10,  
33,1,11,  
33,1,12,  
33,1,13,  
33,1,14,  
33,1,15,  
33,1,16,  
33,1,17,  
33,1,18,  
33,1,19,  
33,1,20,  
33,1,21,  
41,1,10,  
41,1,11,  
41,1,12,  
41,1,13,  
41,1,14,  
41,1,15,  
41,1,16,  
41,1,17,  
41,1,18,  
41,1,19,  
41,1,20,  
41,1,21,  
58,1,10,  
58,1,11,  
58,1,12,  
58,1,13,  
58,1,14,  
58,1,15,  
58,1,16,  
58,1,17,  
58,1,18,  
58,1,19,  
58,1,20,  
58,1,21,  
1,1,yr,m,8,8,8,  
8,  
aqueous saturation,,  
aqueous pressure,Pa,  
aqueous moisture content,,  
znc aqueous vol,m/yr,  
solute aqueous concentration,H-3,,  
solute aqueous concentration,I-129,,  
solute aqueous concentration,Tc-99,,  
solute aqueous concentration,U-235,,  
12,  
#1,yr,  
10,yr,  
100,yr,  
200,yr,  
500,yr,  
1000,yr,

1200, yr,  
1500, yr,  
2000, yr,  
#2500, yr,  
5000, yr,  
10000, yr,  
#20000, yr,  
50000, yr,  
100000, yr,  
#200000, yr,  
8,  
aqueous saturation,,  
aqueous pressure, Pa,  
aqueous moisture content,,  
znc aqueous vol, m/yr,  
solute aqueous concentration, H-3,,  
solute aqueous concentration, I-129,,  
solute aqueous concentration, Tc-99,,  
solute aqueous concentration, U-235,,  
rock/soil type,,

### E.3. NATURAL RECHARGE, SURROGATES 4 – 8 INPUT

~Simulation Title Card  
1,  
B Pond Lengthwise Cross Section,  
WJ McMahon,  
CH2M Hill Hanford,  
July 23 2001,  
10:00 AM PDT,  
3,  
This input file is the contaminant transport run for the INEEL ICDF simulation  
This construction uses the geology developed by Pete Martian  
The input parameters are based on PM reports

~Solution Control Card  
Restart,restart,  
Water w/ Solute Transport,  
9,  
0,day,20,yr,0.0007,yr,0.02,yr,1.25,8,1.e-6,  
20,yr,50,yr,0.02,yr,0.05,yr,1.25,8,1.e-6,  
50,yr,100,yr,0.05,yr,0.10,yr,1.25,8,1.e-6,  
100,yr,500,yr,0.10,yr,0.50,yr,1.25,8,1.e-6,  
500,yr,1000,yr,0.50,yr,2,yr,1.25,8,1.e-6,  
1000,yr,5000,yr,2,yr,10,yr,1.25,8,1.e-6,  
5000,yr,10000,yr,10,yr,100,yr,1.25,8,1.e-6,  
10000,yr,100000,yr,100,yr,1000,yr,1.25,8,1.e-6,  
100000,yr,1000000,yr,1000,yr,10000,yr,1.25,8,1.e-6,  
8000,  
0,

~Grid Card  
cartesian,  
60,1,98,  
# X Dimensions:::160 m ICDF cell Total X Dimension 320 m  
0.,m,6@15,m,5@10,m,2@5,m,2@5,m,  
#20 m to screening model compliance point,  
2@5,m,1@4.,m,1@3.,m,1@2.,m,1@1.,m,  
#190 feet (or 58 m) to edge of landfill cap (less 20 m above)  
2@2.,m,1@3,m,1@4.,m,2@6.,m,1@4.,m,2@3.,m,2@2,m,1@1.,m,  
#190 feet (or 58 m) plus 20 m (less 58 m above)  
2@2.,m,1@3,m,1@4.,m,2@3.,m,1@2,m,1@1.,m,  
#190 feet (or 58 m) plus 100 m (less 78 m above)  
2@2.,m,1@3,m,2@4.,m,2@5.,m,5@8.,m,1@5.,m,1@4.,m,1@3.,m,1@2,m,1@1.,m,  
#One grid block to move last observation point off of boundary  
2@1.,m,  
# Y Dimensions (Y dimension not used)  
0.,m,1.,m,  
# Z Dimensions  
#Basalt Aquifer (Total = 76 m, Begin and End Lower 61 m) 9 Rows (Ignore 0)  
0.,m,2@12.,m,2@8.,m,2@6.,m,1@4.,m,1@3.,m,1@2.,m,  
#Basalt Aquifer Begin First 9 m of Upper 15 m 6 Rows  
6@1.5,m,  
#Basalt Aquifer Begin and End Upper 6 m  
# (7 m or 22 ft-note 6 m saturated and 1 m above water table) 6 Rows  
1@1,m,1@1,m,1@1,m,1@1,m,1@1,m,1@2,m,

```
#Basalt (16.98 m or 57 ft-note that 1 m added to aquifer layer, 17.98 m = 59
ft)
# 7 Rows
1@2,m,1@2.32,m,1@2.75,m,1@3.25,m,1@3,m,1@2.15,m,1@1.51,m,
#Sedimentary Interbed (7.01 m or 23 ft) 4 Rows
1@1.51,m,1@2,m,1@2,m,1@1.5,m,
#Basalt (39.93 m or 131 ft) 13 Rows
1@1.5,m,1@2,m,1@3,m,1@4,m,1@4,m,1@4.5,m,1@4.5,m,1@4,m,1@3,m,1@2.4,m,
1@1.81,m,1@1.22,m,
#Sedimentary Interbed (4.88 m or 16 ft) 4 Rows
1@1.22,m,1@1.22,m,1@1.22,m,1@1.22,m,
#Basalt (23.47 m or 77 ft) 9 Rows
1@1.22,m,1@2,m,1@3,m,1@3.5,m,1@3.75,m,1@3.5,m,1@3,m,1@2,m,1@1.5,m,
#Sedimentary Interbed (11.89 m or 39 ft) 6 Rows
1@1.5,m,1@1.94,m,1@2.45,m,1@2.45,m,1@2.15,m,1@1.4,m,
#Basalt (26.52 m or 87 ft) 13 Rows
1@1.4,m,1@2,m,1@2,m,1@3,m,1@5,m,1@5,m,1@3,m,1@1.57,m,1@1.2,m,1@1,m,1@0.6,m,
1@0.45,m,1@0.3,m,
#Alluvium changed from 9 to 5 feet (1.52 m or 5 ft) 4 Rows
1@0.30,m,1@0.46,m,1@0.46,m,1@0.30,m,
#Clay Liner (0.91 m or 3 ft) 3 Rows
1@0.30,m,1@0.31,m,1@0.30,m,
#Operations Layer (0.91 m or 3 ft) 3 Rows
1@0.30,m,1@0.31,m,1@0.30,m,
#Waste (10.40 m or 34 ft adjusted to 12.56 m to account for cube vs
trapezoid)
# 11 Rows
1@0.5,m,1@0.5,m,1@1,m,1@1,m,1@1.64,m,1@1.64,m,1@1.64,m,1@1.64,m,1@1,m,1
@1,m,
```

~Rock/Soil Zonation Card

```
14,
#Lower 61 m of Basalt Aquifer
Basalt Aquifer,1,60,1,1,1,9,
#Begin First 9 m of Upper 15 m of Basalt Aquifer
Basalt Aquifer,1,60,1,1,10,15,
#Upper 6 m of Basalt Aquifer
Basalt Aquifer,1,60,1,1,16,21,
#Lowest Vadose Basalt Layer
Basalt,1,60,1,1,22,28,
Interbed,1,60,1,1,29,32,
Basalt,1,60,1,1,33,45,
Interbed,1,60,1,1,46,49,
Basalt,1,60,1,1,50,58,
Interbed,1,60,1,1,59,64,
Basalt,1,60,1,1,65,77,
Alluvium,1,60,1,1,78,81,
Clay,1,60,1,1,82,84,
Operation Gravelly Sand,1,60,1,1,85,87,
Waste Gravelly Sand,1,60,1,1,88,98,
```

~Inactive Nodes Card

```
#Integer,
1,
16,60,1,1,22,98,
```

~Mechanical Properties Card

```
#Particle density = 2650 kg/m^3 except for clay and old alluvium
#Subgrade, attenuation barrier, and drain rock used in earlier models but
#not used here
#Basalt and interbed properties from P. Martian Screening Model
Basalt Aquifer,,,0.06,0.06,,,Millington and Quirk,
Interbed,,,0.487,0.487,,,Millington and Quirk,
Basalt,,,0.05,0.05,,,Millington and Quirk,
#
#Old Alluvium characteristics from Geotech report measurements
# sat. moisture content (0.422, 0.426); dry bulk density (1.60, 1.64 g/cm^3)
# particle density = 1.62 g/cm^3/(1-0.424) = 2.8125 g/cm^3
Alluvium,2812.5,kg/m^3,0.424,0.424,,,Millington and Quirk,
#Attenuation Barrier,,,0.400,0.400,,,Millington and Quirk,
#Clay characteristics per discussion with J. Dehner
Clay,2600,kg/m^3,0.390,0.390,,,Millington and Quirk,
#Drain Rock,,,0.400,0.400,,,Millington and Quirk,
Operation Gravelly Sand,,,0.275,0.275,,,Millington and Quirk,
#Operation Gravelly Sand dry bulk density = 120 lb/ft^3 (per J. Dehner)
#120 lb/ft^3*0.4536 kg/lb*1 ft^3/(0.3048 m/ft)^3 = 1922.25 kg/m^3
#Porosity Operation Gravelly Sand = 1-(1922.25/2650)= 0.275
Waste Gravelly Sand,,,0.266,0.266,,,Millington and Quirk,
#Waste Gravelly Sand dry bulk density = 121.5 lb/ft^3 (per J. Dehner)
#121.5 lb/ft^3*0.4536 kg/lb*1 ft^3/(0.3048 m)^3 = 1946.28 kg/m^3
#Porosity Waste Gravelly Sand = 1-(1946.28/2650)= 0.266
```

```
~Hydraulic Properties Card
#Properties from P. Martian Screening Model except old alluvium
Basalt Aquifer,9.00e+01,darcy,,,3.00e-01,darcy,
Interbed,6.7e-5,hc:cm/s,,,6.7e-5,hc:cm/s,
Basalt,9.00e+01,darcy,,,3.00e-01,darcy,
#Old Alluvium characteristics from Geotech report measurements
# sat. hydraulic conductivity (1.2e-07 cm/s, 6.2e-08 cm/s, 7.1e-08 cm/s)
Alluvium,1.2e-07,hc:cm/s,,,1.2e-07,hc:cm/s,
#Subgrade,1e-04,hc:cm/s,,,1e-04,hc:cm/s,
#Attenuation Barrier,1e-07,hc:cm/s,,,1e-07,hc:cm/s,
Clay,1e-07,hc:cm/s,,,1e-07,hc:cm/s,
#Drain Rock,3.0e-01,hc:cm/s,,,3.0e-01,hc:cm/s,
Operation Gravelly Sand,1e-04,hc:cm/s,,,1e-04,hc:cm/s,
Waste Gravelly Sand,1e-03,hc:cm/s,,,1e-03,hc:cm/s,
```

```
~Saturation Function Card
#Parameters from P. Martian Screening Model except old alluvium
#alpha, n, theta R, m
#m only specified for basalts, otherwise default m = 1 - 1/n
Basalt Aquifer,Nonhysteretic van Genuchten,4.0,1/m,4.5,0.0002,0.7777778,
Interbed,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.142,,,
Basalt,Nonhysteretic van Genuchten,4.0,1/m,4.5,0.0002,0.7777778,
#Old Alluvium characteristics from RETC fitting of Geotech report
measurements
Alluvium,Nonhysteretic van Genuchten,0.595,1/m,1.09,0.142,,,
#Subgrade,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.142,,,
#Attenuation Barrier,Nonhysteretic van Genuchten,0.800,1/m,1.090,0.07,,,
Clay,Nonhysteretic van Genuchten,0.800,1/m,1.109,0.07,,,
#Drain Rock,Nonhysteretic van Genuchten,493,1/m,2.190,0.005,,,
Operation Gravelly Sand,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.083,,,
Waste Gravelly Sand,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.072,,,
#
```

~Aqueous Relative Permeability Card  
#m only specified for basalts, otherwise default m = 1 - 1/n  
Basalt Aquifer,Mualem,1.9,  
Interbed,Mualem,,  
Basalt,Mualem,1.9,  
Alluvium,Mualem,,  
#Subgrade,Mualem,,  
#Attenuation Barrier,Mualem,,  
Clay,Mualem,,  
#Drain Rock,Mualem,,  
Operation Gravelly Sand,Mualem,,  
Waste Gravelly Sand,Mualem,,  
#

~Solute/Fluid Interactions Card

4,  
#H-3,conventional,1.0e-09,m^2/s,noncontinuous,,,  
#I-129,conventional,1.0e-09,m^2/s,noncontinuous,,,  
#Tc-99,conventional,1.0e-09,m^2/s,noncontinuous,,,  
#U-235,conventional,1.0e-09,m^2/s,noncontinuous,,,  
Np-237,conventional,1.0e-09,m^2/s,noncontinuous,,,  
Sr-90,conventional,1.0e-09,m^2/s,noncontinuous,,,  
Zn-65,conventional,1.0e-09,m^2/s,noncontinuous,,,  
Eu-155,conventional,1.0e-09,m^2/s,noncontinuous,,,  
0,  
#

~Solute/Porous Media Interaction Card

Basalt Aquifer,6.0,m,3.0,m,

#H-3,0.0,cm^3/g,  
#I-129,0.0,cm^3/g,  
#Tc-99,0.008,cm^3/g,  
#U-235,0.24,cm^3/g,  
Np-237,0.32,cm^3/g,  
Sr-90,0.48,cm^3/g,  
Zn-65,0.64,cm^3/g,  
Eu-155,314,cm^3/g,  
#

Interbed,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
#I-129,0.0,cm^3/g,  
#Tc-99,0.2,cm^3/g,  
#U-235,6.0,cm^3/g,  
Np-237,8.0,cm^3/g,  
Sr-90,12.0,cm^3/g,  
Zn-65,16.0,cm^3/g,  
Eu-155,340,cm^3/g,  
#

Basalt,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
#I-129,0.0,cm^3/g,  
#Tc-99,0.0,cm^3/g,  
#U-235,0.0,cm^3/g,  
Np-237,0.0,cm^3/g,  
Sr-90,0.0,cm^3/g,  
Zn-65,0.0,cm^3/g,  
Eu-155,0.0,cm^3/g,  
#

```
#Subgrade, 5.0,m,0,m,
#
Alluvium,5.0,m,0,m,
#H-3,0.0,cm^3/g,
#I-129,0.0,cm^3/g,
#Tc-99,0.2,cm^3/g,
#U-235,6.0,cm^3/g,
Np-237,8.0,cm^3/g,
Sr-90,24.0,cm^3/g,
Zn-65,16.0,cm^3/g,
Eu-155,340,cm^3/g,
#
#Attenuation Barrier,5.0,m,0,m,
#H-3,0.0,cm^3/g,
#I-129,1.0,cm^3/g,
#Tc-99,1.0,cm^3/g,
#U-235,63.0,cm^3/g,
#Np-237,55.0,cm^3/g,
#Sr-90,200.0,cm^3/g,
#Zn-65,2400.0,cm^3/g,
#Eu-155,340,cm^3/g,
#
Clay,5.0,m,0,m,
#H-3,0.0,cm^3/g,
#I-129,1.0,cm^3/g,
#Tc-99,1.0,cm^3/g,
#U-235,63.0,cm^3/g,
Np-237,55.0,cm^3/g,
Sr-90,200.0,cm^3/g,
Zn-65,2400.0,cm^3/g,
Eu-155,340,cm^3/g,
#
#Drain Rock,5.0,m,0,m,
#H-3,0.0,cm^3/g,
#I-129,0.0,cm^3/g,
#Tc-99,0.2,cm^3/g,
#U-235,6.0,cm^3/g,
#Np-237,8.0,cm^3/g,
#Sr-90,24.0,cm^3/g,
#Zn-65,16.0,cm^3/g,
#Eu-155,340,cm^3/g,
#
Operation Gravelly Sand,5.0,m,0,m,
#H-3,0.0,cm^3/g,
#I-129,0.0,cm^3/g,
#Tc-99,0.2,cm^3/g,
#U-235,6.0,cm^3/g,
Np-237,8.0,cm^3/g,
Sr-90,12.0,cm^3/g,
Zn-65,16.0,cm^3/g,
Eu-155,340,cm^3/g,
#
Waste Gravelly Sand,5.0,m,0,m,
#H-3,0.0,cm^3/g,
#I-129,0.0,cm^3/g,
#Tc-99,0.2,cm^3/g,
#U-235,6.0,cm^3/g,
```

Np-237,8.0,cm^3/g,  
Sr-90,12.0,cm^3/g,  
Zn-65,16.0,cm^3/g,  
Eu-155,340,cm^3/g,  
#  
~Initial Conditions Card  
Gas Pressure,Aqueous Pressure,  
9,  
Aqueous Pressure,,,,,,,1,60,1,1,1,83,  
#Solute Volume Overwrite,H-3,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,  
#Solute Volume Overwrite,I-129,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,  
#Solute Volume Overwrite,Tc-99,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,  
#Solute Volume Overwrite,U-235,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,Np-237,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,Sr-90,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,Zn-65,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,Eu-155,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,  
#  
#Solute Volume Overwrite,H-3,2.0e+03,1/m^3,0,,0,,0,,1,15,1,1,88,98,  
#Solute Volume Overwrite,I-129,2.0e+03,1/m^3,0,,0,,0,,1,15,1,1,88,98,  
#Solute Volume Overwrite,Tc-99,2.0e+03,1/m^3,0,,0,,0,,1,15,1,1,88,98,  
#Solute Volume Overwrite,U-235,2.0e+03,1/m^3,0,,0,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,Np-237,1946.28,1/m^3,0,,0,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,Sr-90,1946.28,1/m^3,0,,0,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,Zn-65,1946.28,1/m^3,0,,0,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,Eu-155,1946.28,1/m^3,0,,0,,0,,1,15,1,1,88,98,  
  
~Boundary Conditions Card  
4,  
#  
top,neumann,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#0.01 m/yr \* 1.74 ICDF Recharge Ratio = 0.0174 m/yr  
1,15,1,1,98,98,1,  
0,day,-0.0174,m/yr,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#  
west,neumann,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
1,1,1,1,20,1,  
0,day,0.06,m/day,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#  
west,neumann,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
1,1,1,1,21,21,1,  
0,day,0.03,m/day,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#  
east,hydraulic gradient,outflow,outflow,outflow,outflow,  
#Hold head constant to keep h ~ 5 m at compliance point

```
60,60,1,1,1,21,1,  
0,day,786871.34,Pa,,.,.,.,.,.,.,.,.  
#  
~Surface Flux Card  
50,  
Aqueous Volumetric Flux,m^3/yr,m^3,bottom,1,15,1,1,82,82,  
#Solute Flux,H-3,1/yr,,bottom,1,15,1,1,82,82,  
#Solute Flux,I-129,1/yr,,bottom,1,15,1,1,82,82,  
#Solute Flux,Tc-99,1/yr,,bottom,1,15,1,1,82,82,  
#Solute Flux,U-235,1/yr,,bottom,1,15,1,1,82,82,  
Solute Flux,Np-237,1/yr,,bottom,1,15,1,1,82,82,  
Solute Flux,Sr-90,1/yr,,bottom,1,15,1,1,82,82,  
Solute Flux,Zn-65,1/yr,,bottom,1,15,1,1,82,82,  
Solute Flux,Eu-155,1/yr,,bottom,1,15,1,1,82,82,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,bottom,1,15,1,1,22,22,  
#Solute Flux,H-3,1/yr,,bottom,1,15,1,1,22,22,  
#Solute Flux,I-129,1/yr,,bottom,1,15,1,1,22,22,  
#Solute Flux,Tc-99,1/yr,,bottom,1,15,1,1,22,22,  
#Solute Flux,U-235,1/yr,,bottom,1,15,1,1,22,22,  
Solute Flux,Np-237,1/yr,,bottom,1,15,1,1,22,22,  
Solute Flux,Sr-90,1/yr,,bottom,1,15,1,1,22,22,  
Solute Flux,Zn-65,1/yr,,bottom,1,15,1,1,22,22,  
Solute Flux,Eu-155,1/yr,,bottom,1,15,1,1,22,22,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,21,21,1,1,10,21,  
#Solute Flux,H-3,1/yr,,west,21,21,1,1,10,21,  
#Solute Flux,I-129,1/yr,,west,21,21,1,1,10,21,  
#Solute Flux,Tc-99,1/yr,,west,21,21,1,1,10,21,  
#Solute Flux,U-235,1/yr,,west,21,21,1,1,10,21,  
Solute Flux,Np-237,1/yr,,west,21,21,1,1,10,21,  
Solute Flux,Sr-90,1/yr,,west,21,21,1,1,10,21,  
Solute Flux,Zn-65,1/yr,,west,21,21,1,1,10,21,  
Solute Flux,Eu-155,1/yr,,west,21,21,1,1,10,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,21,21,1,1,17,21,  
#Solute Flux,H-3,1/yr,,west,21,21,1,1,17,21,  
#Solute Flux,I-129,1/yr,,west,21,21,1,1,17,21,  
#Solute Flux,Tc-99,1/yr,,west,21,21,1,1,17,21,  
#Solute Flux,U-235,1/yr,,west,21,21,1,1,17,21,  
Solute Flux,Np-237,1/yr,,west,21,21,1,1,17,21,  
Solute Flux,Sr-90,1/yr,,west,21,21,1,1,17,21,  
Solute Flux,Zn-65,1/yr,,west,21,21,1,1,17,21,  
Solute Flux,Eu-155,1/yr,,west,21,21,1,1,17,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,33,33,1,1,10,21,  
#Solute Flux,H-3,1/yr,,west,33,33,1,1,10,21,  
#Solute Flux,I-129,1/yr,,west,33,33,1,1,10,21,  
#Solute Flux,Tc-99,1/yr,,west,33,33,1,1,10,21,  
#Solute Flux,U-235,1/yr,,west,33,33,1,1,10,21,  
Solute Flux,Np-237,1/yr,,west,33,33,1,1,10,21,  
Solute Flux,Sr-90,1/yr,,west,33,33,1,1,10,21,  
Solute Flux,Zn-65,1/yr,,west,33,33,1,1,10,21,  
Solute Flux,Eu-155,1/yr,,west,33,33,1,1,10,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,33,33,1,1,17,21,  
#Solute Flux,H-3,1/yr,,west,33,33,1,1,17,21,
```

```
#Solute Flux,I-129,1/yr,,west,33,33,1,1,17,21,  
#Solute Flux,Tc-99,1/yr,,west,33,33,1,1,17,21,  
#Solute Flux,U-235,1/yr,,west,33,33,1,1,17,21,  
Solute Flux,Np-237,1/yr,,west,33,33,1,1,17,21,  
Solute Flux,Sr-90,1/yr,,west,33,33,1,1,17,21,  
Solute Flux,Zn-65,1/yr,,west,33,33,1,1,17,21,  
Solute Flux,Eu-155,1/yr,,west,33,33,1,1,17,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,41,41,1,1,10,21,  
#Solute Flux,H-3,1/yr,,west,41,41,1,1,10,21,  
#Solute Flux,I-129,1/yr,,west,41,41,1,1,10,21,  
#Solute Flux,Tc-99,1/yr,,west,41,41,1,1,10,21,  
#Solute Flux,U-235,1/yr,,west,41,41,1,1,10,21,  
Solute Flux,Np-237,1/yr,,west,41,41,1,1,10,21,  
Solute Flux,Sr-90,1/yr,,west,41,41,1,1,10,21,  
Solute Flux,Zn-65,1/yr,,west,41,41,1,1,10,21,  
Solute Flux,Eu-155,1/yr,,west,41,41,1,1,10,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,41,41,1,1,17,21,  
#Solute Flux,H-3,1/yr,,west,41,41,1,1,17,21,  
#Solute Flux,I-129,1/yr,,west,41,41,1,1,17,21,  
#Solute Flux,Tc-99,1/yr,,west,41,41,1,1,17,21,  
#Solute Flux,U-235,1/yr,,west,41,41,1,1,17,21,  
Solute Flux,Np-237,1/yr,,west,41,41,1,1,17,21,  
Solute Flux,Sr-90,1/yr,,west,41,41,1,1,17,21,  
Solute Flux,Zn-65,1/yr,,west,41,41,1,1,17,21,  
Solute Flux,Eu-155,1/yr,,west,41,41,1,1,17,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,58,58,1,1,10,21,  
#Solute Flux,H-3,1/yr,,west,58,58,1,1,10,21,  
#Solute Flux,I-129,1/yr,,west,58,58,1,1,10,21,  
#Solute Flux,Tc-99,1/yr,,west,58,58,1,1,10,21,  
#Solute Flux,U-235,1/yr,,west,58,58,1,1,10,21,  
Solute Flux,Np-237,1/yr,,west,58,58,1,1,10,21,  
Solute Flux,Sr-90,1/yr,,west,58,58,1,1,10,21,  
Solute Flux,Zn-65,1/yr,,west,58,58,1,1,10,21,  
Solute Flux,Eu-155,1/yr,,west,58,58,1,1,10,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,58,58,1,1,17,21,  
#Solute Flux,H-3,1/yr,,west,58,58,1,1,17,21,  
#Solute Flux,I-129,1/yr,,west,58,58,1,1,17,21,  
#Solute Flux,Tc-99,1/yr,,west,58,58,1,1,17,21,  
#Solute Flux,U-235,1/yr,,west,58,58,1,1,17,21,  
Solute Flux,Np-237,1/yr,,west,58,58,1,1,17,21,  
Solute Flux,Sr-90,1/yr,,west,58,58,1,1,17,21,  
Solute Flux,Zn-65,1/yr,,west,58,58,1,1,17,21,  
Solute Flux,Eu-155,1/yr,,west,58,58,1,1,17,21,  
#  
~Output Control Card  
48,  
21,1,10,  
21,1,11,  
21,1,12,  
21,1,13,  
21,1,14,  
21,1,15,
```

21,1,16,  
21,1,17,  
21,1,18,  
21,1,19,  
21,1,20,  
21,1,21,  
33,1,10,  
33,1,11,  
33,1,12,  
33,1,13,  
33,1,14,  
33,1,15,  
33,1,16,  
33,1,17,  
33,1,18,  
33,1,19,  
33,1,20,  
33,1,21,  
41,1,10,  
41,1,11,  
41,1,12,  
41,1,13,  
41,1,14,  
41,1,15,  
41,1,16,  
41,1,17,  
41,1,18,  
41,1,19,  
41,1,20,  
41,1,21,  
58,1,10,  
58,1,11,  
58,1,12,  
58,1,13,  
58,1,14,  
58,1,15,  
58,1,16,  
58,1,17,  
58,1,18,  
58,1,19,  
58,1,20,  
58,1,21,  
1,1,yr,m,8,8,8,  
8,  
aqueous saturation,,  
aqueous pressure,Pa,  
aqueous moisture content,,  
znc aqueous vol,m/yr,  
solute aqueous concentration,Np-237,,  
solute aqueous concentration,Sr-90,,  
solute aqueous concentration,Zn-65,,  
solute aqueous concentration,Eu-155,,  
12,  
#1,yr,  
10,yr,  
100,yr,  
200,yr,

500, yr,  
1000, yr,  
1200, yr,  
1500, yr,  
2000, yr,  
#2500, yr,  
5000, yr,  
10000, yr,  
#20000, yr,  
50000, yr,  
100000, yr,  
#200000, yr,  
8,  
aqueous saturation,,  
aqueous pressure, Pa,  
aqueous moisture content,,  
znc aqueous vol, m/yr,  
solute aqueous concentration, Np-237,,  
solute aqueous concentration, Sr-90,,  
solute aqueous concentration, Zn-65,,  
solute aqueous concentration, Eu-155,,  
rock/soil type,,

## E.4. Natural Recharge, Surrogates 9 – 12 Input

~Simulation Title Card

1,  
B Pond Lengthwise Cross Section,  
WJ McMahon,  
CH2M Hill Hanford,  
July 23 2001,  
10:00 AM PDT,  
3,  
This input file is the contaminant transport run for the INEEL ICDF simulation  
This construction uses the geology developed by Pete Martian  
The input parameters are based on PM reports

~Solution Control Card

Restart,restart,  
Water w/ Solute Transport,  
9,  
0,day,20,yr,0.0007,yr,0.02,yr,1.25,8,1.e-6,  
20,yr,50,yr,0.02,yr,0.05,yr,1.25,8,1.e-6,  
50,yr,100,yr,0.05,yr,0.10,yr,1.25,8,1.e-6,  
100,yr,500,yr,0.10,yr,0.5,yr,1.25,8,1.e-6,  
500,yr,1000,yr,0.5,yr,2,yr,1.25,8,1.e-6,  
1000,yr,5000,yr,2,yr,10,yr,1.25,8,1.e-6,  
5000,yr,10000,yr,10,yr,100,yr,1.25,8,1.e-6,  
10000,yr,100000,yr,100,yr,1000,yr,1.25,8,1.e-6,  
100000,yr,1000000,yr,1000,yr,10000,yr,1.25,8,1.e-6,  
8000,  
0,

~Grid Card

cartesian,  
60,1,98,  
# X Dimensions::160 m ICDF cell Total X Dimension 320 m  
0.,m,6@15,m,5@10,m,2@5,m,2@5,m,  
#20 m to screening model compliance point,  
2@5,m,1@4.,m,1@3.,m,1@2.,m,1@1.,m,  
#190 feet (or 58 m) to edge of landfill cap (less 20 m above)  
2@2.,m,1@3,m,1@4.,m,2@6.,m,1@4.,m,2@3.,m,2@2,m,1@1.,m,  
#190 feet (or 58 m) plus 20 m (less 58 m above)  
2@2.,m,1@3,m,1@4.,m,2@3.,m,1@2,m,1@1.,m,  
#190 feet (or 58 m) plus 100 m (less 78 m above)  
2@2.,m,1@3,m,2@4.,m,2@5.,m,5@8.,m,1@5.,m,1@4.,m,1@3.,m,1@2,m,1@1.,m,  
#One grid block to move last observation point off of boundary  
2@1.,m,  
# Y Dimensions (Y dimension not used)  
0.,m,1.,m,  
# Z Dimensions  
#Basalt Aquifer (Total = 76 m, Begin and End Lower 61 m) 9 Rows (Ignore 0)  
0.,m,2@12.,m,2@8.,m,2@6.,m,1@4.,m,1@3.,m,1@2.,m,  
#Basalt Aquifer Begin First 9 m of Upper 15 m 6 Rows  
6@1.5,m,  
#Basalt Aquifer Begin and End Upper 6 m  
# (7 m or 22 ft-note 6 m saturated and 1 m above water table) 6 Rows  
1@1,m,1@1,m,1@1,m,1@1,m,1@1,m,1@2,m,

```
#Basalt (16.98 m or 57 ft-note that 1 m added to aquifer layer, 17.98 m = 59
ft)
# 7 Rows
1@2,m,1@2.32,m,1@2.75,m,1@3.25,m,1@3,m,1@2.15,m,1@1.51,m,
#Sedimentary Interbed (7.01 m or 23 ft) 4 Rows
1@1.51,m,1@2,m,1@2,m,1@1.5,m,
#Basalt (39.93 m or 131 ft) 13 Rows
1@1.5,m,1@2,m,1@3,m,1@4,m,1@4,m,1@4.5,m,1@4.5,m,1@4,m,1@3,m,1@2.4,m,
1@1.81,m,1@1.22,m,
#Sedimentary Interbed (4.88 m or 16 ft) 4 Rows
1@1.22,m,1@1.22,m,1@1.22,m,1@1.22,m,
#Basalt (23.47 m or 77 ft) 9 Rows
1@1.22,m,1@2,m,1@3,m,1@3.5,m,1@3.75,m,1@3.5,m,1@3,m,1@2,m,1@1.5,m,
#Sedimentary Interbed (11.89 m or 39 ft) 6 Rows
1@1.5,m,1@1.94,m,1@2.45,m,1@2.45,m,1@2.15,m,1@1.4,m,
#Basalt (26.52 m or 87 ft) 13 Rows
1@1.4,m,1@2,m,1@2,m,1@3,m,1@5,m,1@5,m,1@3,m,1@1.57,m,1@1.2,m,1@1,m,1@0.6,m,
1@0.45,m,1@0.3,m,
#Alluvium changed from 9 to 5 feet (1.52 m or 5 ft) 4 Rows
1@0.30,m,1@0.46,m,1@0.46,m,1@0.30,m,
#Clay Liner (0.91 m or 3 ft) 3 Rows
1@0.30,m,1@0.31,m,1@0.30,m,
#Operations Layer (0.91 m or 3 ft) 3 Rows
1@0.30,m,1@0.31,m,1@0.30,m,
#Waste (10.40 m or 34 ft adjusted to 12.56 m to account for cube vs
trapezoid)
# 11 Rows
1@0.5,m,1@0.5,m,1@1,m,1@1,m,1@1.64,m,1@1.64,m,1@1.64,m,1@1.64,m,1@1,m,1@1,m,1
@1,m,
```

~Rock/Soil Zonation Card

```
14,
#Lower 61 m of Basalt Aquifer
Basalt Aquifer,1,60,1,1,1,9,
#Begin First 9 m of Upper 15 m of Basalt Aquifer
Basalt Aquifer,1,60,1,1,10,15,
#Upper 6 m of Basalt Aquifer
Basalt Aquifer,1,60,1,1,16,21,
#Lowest Vadose Basalt Layer
Basalt,1,60,1,1,22,28,
Interbed,1,60,1,1,29,32,
Basalt,1,60,1,1,33,45,
Interbed,1,60,1,1,46,49,
Basalt,1,60,1,1,50,58,
Interbed,1,60,1,1,59,64,
Basalt,1,60,1,1,65,77,
Alluvium,1,60,1,1,78,81,
Clay,1,60,1,1,82,84,
Operation Gravelly Sand,1,60,1,1,85,87,
Waste Gravelly Sand,1,60,1,1,88,98,
```

~Inactive Nodes Card

```
#Integer,
1,
16,60,1,1,22,98,
```

~Mechanical Properties Card

```
#Particle density = 2650 kg/m^3 except for clay and old alluvium
#Subgrade, attenuation barrier, and drain rock used in earlier models but
#not used here
#Basalt and interbed properties from P. Martian Screening Model
Basalt Aquifer,,,0.06,0.06,,,Millington and Quirk,
Interbed,,,0.487,0.487,,,Millington and Quirk,
Basalt,,,0.05,0.05,,,Millington and Quirk,
#
#Old Alluvium characteristics from Geotech report measurements
# sat. moisture content (0.422, 0.426); dry bulk density (1.60, 1.64 g/cm^3)
# particle density = 1.62 g/cm^3/(1-0.424) = 2.8125 g/cm^3
Alluvium,2812.5,kg/m^3,0.424,0.424,,,Millington and Quirk,
#Attenuation Barrier,,,0.400,0.400,,,Millington and Quirk,
#Clay characteristics per discussion with J. Dehner
Clay,2600,kg/m^3,0.390,0.390,,,Millington and Quirk,
#Drain Rock,,,0.400,0.400,,,Millington and Quirk,
Operation Gravelly Sand,,,0.275,0.275,,,Millington and Quirk,
#Operation Gravelly Sand dry bulk density = 120 lb/ft^3 (per J. Dehner)
#120 lb/ft^3*0.4536 kg/lb*1 ft^3/(0.3048 m/ft)^3 = 1922.25 kg/m^3
#Porosity Operation Gravelly Sand = 1-(1922.25/2650)= 0.275
Waste Gravelly Sand,,,0.266,0.266,,,Millington and Quirk,
#Waste Gravelly Sand dry bulk density = 121.5 lb/ft^3 (per J. Dehner)
#121.5 lb/ft^3*0.4536 kg/lb*1 ft^3/(0.3048 m)^3 = 1946.28 kg/m^3
#Porosity Waste Gravelly Sand = 1-(1946.28/2650)= 0.266
```

```
~Hydraulic Properties Card
#Properties from P. Martian Screening Model except old alluvium
Basalt Aquifer,9.00e+01,darcy,,,3.00e-01,darcy,
Interbed,6.7e-5,hc:cm/s,,,6.7e-5,hc:cm/s,
Basalt,9.00e+01,darcy,,,3.00e-01,darcy,
#Old Alluvium characteristics from Geotech report measurements
# sat. hydraulic conductivity (1.2e-07 cm/s, 6.2e-08 cm/s, 7.1e-08 cm/s)
Alluvium,1.2e-07,hc:cm/s,,,1.2e-07,hc:cm/s,
#Subgrade,1e-04,hc:cm/s,,,1e-04,hc:cm/s,
#Attenuation Barrier,1e-07,hc:cm/s,,,1e-07,hc:cm/s,
Clay,1e-07,hc:cm/s,,,1e-07,hc:cm/s,
#Drain Rock,3.0e-01,hc:cm/s,,,3.0e-01,hc:cm/s,
Operation Gravelly Sand,1e-04,hc:cm/s,,,1e-04,hc:cm/s,
Waste Gravelly Sand,1e-03,hc:cm/s,,,1e-03,hc:cm/s,
```

```
~Saturation Function Card
#Parameters from P. Martian Screening Model except old alluvium
#alpha, n, theta R, m
#m only specified for basalts, otherwise default m = 1 - 1/n
Basalt Aquifer,Nonhysteretic van Genuchten,4.0,1/m,4.5,0.0002,0.7777778,
Interbed,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.142,,,
Basalt,Nonhysteretic van Genuchten,4.0,1/m,4.5,0.0002,0.7777778,
#Old Alluvium characteristics from RETC fitting of Geotech report
measurements
Alluvium,Nonhysteretic van Genuchten,0.595,1/m,1.09,0.142,,,
#Subgrade,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.142,,,
#Attenuation Barrier,Nonhysteretic van Genuchten,0.800,1/m,1.090,0.07,,,
Clay,Nonhysteretic van Genuchten,0.800,1/m,1.109,0.07,,,
#Drain Rock,Nonhysteretic van Genuchten,493,1/m,2.190,0.005,,,
Operation Gravelly Sand,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.083,,,
Waste Gravelly Sand,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.072,,,
#
```

```
~Aqueous Relative Permeability Card
#m only specified for basalts, otherwise default m = 1 - 1/n
Basalt Aquifer,Mualem,1.9,
Interbed,Mualem.,
Basalt,Mualem,1.9,
Alluvium,Mualem.,
#Subgrade,Mualem.,
#Attenuation Barrier,Mualem.,
Clay,Mualem.,
#Drain Rock,Mualem.,
Operation Gravelly Sand,Mualem.,
Waste Gravelly Sand,Mualem.,
#
~Solute/Fluid Interactions Card
4,
#H-3,conventional,1.0e-09,m^2/s,noncontinuous,,,,
I-129A,conventional,1.0e-09,m^2/s,noncontinuous,,,,
I-129B,conventional,1.0e-09,m^2/s,noncontinuous,,,,
#U-235,conventional,1.0e-09,m^2/s,noncontinuous,,,,
#Np-237,conventional,1.0e-09,m^2/s,noncontinuous,,,,
Sr-90,conventional,1.0e-09,m^2/s,noncontinuous,,,,
#Zn-65,conventional,1.0e-09,m^2/s,noncontinuous,,,,
Eu-155,conventional,1.0e-09,m^2/s,noncontinuous,,,,
0,
#
~Solute/Porous Media Interaction Card
Basalt Aquifer,6.0,m,3.0,m,
#H-3,0.0,cm^3/g,
I-129A,0.0,cm^3/g,
I-129B,0.0,cm^3/g,
#U-235,0.24,cm^3/g,
#Np-237,0.32,cm^3/g,
Sr-90,0.48,cm^3/g,
#Zn-65,0.64,cm^3/g,
Eu-155,13.6,cm^3/g,
#
Interbed,5.0,m,0,m,
#H-3,0.0,cm^3/g,
I-129A,0.0,cm^3/g,
I-129B,0.1,cm^3/g,
#U-235,6.0,cm^3/g,
#Np-237,8.0,cm^3/g,
Sr-90,12.0,cm^3/g,
#Zn-65,16.0,cm^3/g,
Eu-155,340,cm^3/g,
#
Basalt,5.0,m,0,m,
#H-3,0.0,cm^3/g,
I-129A,0.0,cm^3/g,
I-129B,0.0,cm^3/g,
#U-235,0.0,cm^3/g,
#Np-237,0.0,cm^3/g,
Sr-90,0.0,cm^3/g,
#Zn-65,0.0,cm^3/g,
Eu-155,0,cm^3/g,
#
#Subgrade,5.0,m,0,m,
```

```
#  
Alluvium,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
I-129A,0.0,cm^3/g,  
I-129B,0.1,cm^3/g,  
#U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,  
Sr-90,24.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
Eu-155,340,cm^3/g,  
#  
#Attenuation Barrier,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
#I-129A,1.0,cm^3/g,  
#I-129B,1.0,cm^3/g,  
#U-235,63.0,cm^3/g,  
#Np-237,55.0,cm^3/g,  
#Sr-90,200.0,cm^3/g,  
#Zn-65,2400.0,cm^3/g,  
#Eu-155,340,cm^3/g,  
#  
Clay,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
I-129A,1.0,cm^3/g,  
I-129B,1.0,cm^3/g,  
#U-235,63.0,cm^3/g,  
#Np-237,55.0,cm^3/g,  
Sr-90,200.0,cm^3/g,  
#Zn-65,2400.0,cm^3/g,  
Eu-155,340,cm^3/g,  
#  
#Drain Rock,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
#I-129A,0.0,cm^3/g,  
#I-129B,0.1,cm^3/g,  
#U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,  
#Sr-90,24.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
#Eu-155,340,cm^3/g,  
#  
Operation Gravelly Sand,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
I-129A,0.0,cm^3/g,  
I-129B,0.1,cm^3/g,  
#U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,  
Sr-90,12.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
Eu-155,340,cm^3/g,  
#  
Waste Gravelly Sand,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
I-129A,0.1,cm^3/g,  
I-129B,0.1,cm^3/g,  
#U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,
```

```
Sr-90,12.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
Eu-155,340,cm^3/g,  
#  
~Initial Conditions Card  
Gas Pressure,Aqueous Pressure,  
9,  
Aqueous Pressure,,,,,,1,60,1,1,1,98,  
#Solute Volume Overwrite,H-3,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,I-129A,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,I-129B,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
#Solute Volume Overwrite,U-235,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
#Solute Volume Overwrite,Np-237,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,Sr-90,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
#Solute Volume Overwrite,Zn-65,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,Eu-155,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
#  
#Solute Volume Overwrite,H-3,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,I-129A,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,I-129B,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
#Solute Volume Overwrite,U-235,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
#Solute Volume Overwrite,Np-237,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,Sr-90,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
#Solute Volume Overwrite,Zn-65,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,Eu-155,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
  
~Boundary Conditions Card  
4,  
#  
top,neumann,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#0.01 m/yr * 1.74 ICDF Recharge Ratio = 0.0174 m/yr  
1,15,1,1,98,98,1,  
0,day,-0.0174,m/yr,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#  
west,neumann,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
1,1,1,1,20,1,  
0,day,0.06,m/day,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#  
west,neumann,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
1,1,1,1,21,1,  
0,day,0.03,m/day,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#  
east,hydraulic gradient,outflow,outflow,outflow,outflow,  
#Hold head constant to keep h ~ 5 m at compliance point  
60,60,1,1,1,21,1,
```

```
0,day,786871.34,Pa,,,,,,,,,,  
#  
~Surface Flux Card  
50,  
Aqueous Volumetric Flux,m^3/yr,m^3,bottom,1,15,1,1,82,82,  
#Solute Flux,H-3,1/yr,,bottom,1,15,1,1,82,82,  
Solute Flux,I-129A,1/yr,,bottom,1,15,1,1,82,82,  
Solute Flux,I-129B,1/yr,,bottom,1,15,1,1,82,82,  
#Solute Flux,U-235,1/yr,,bottom,1,15,1,1,82,82,  
#Solute Flux,Np-237,1/yr,,bottom,1,15,1,1,82,82,  
Solute Flux,Sr-90,1/yr,,bottom,1,15,1,1,82,82,  
#Solute Flux,Zn-65,1/yr,,bottom,1,15,1,1,82,82,  
Solute Flux,Eu-155,1/yr,,bottom,1,15,1,1,82,82,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,bottom,1,15,1,1,22,22,  
#Solute Flux,H-3,1/yr,,bottom,1,15,1,1,22,22,  
Solute Flux,I-129A,1/yr,,bottom,1,15,1,1,22,22,  
Solute Flux,I-129B,1/yr,,bottom,1,15,1,1,22,22,  
#Solute Flux,U-235,1/yr,,bottom,1,15,1,1,22,22,  
#Solute Flux,Np-237,1/yr,,bottom,1,15,1,1,22,22,  
Solute Flux,Sr-90,1/yr,,bottom,1,15,1,1,22,22,  
#Solute Flux,Zn-65,1/yr,,bottom,1,15,1,1,22,22,  
Solute Flux,Eu-155,1/yr,,bottom,1,15,1,1,22,22,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,21,21,1,1,10,21,  
#Solute Flux,H-3,1/yr,,west,21,21,1,1,10,21,  
Solute Flux,I-129A,1/yr,,west,21,21,1,1,10,21,  
Solute Flux,I-129B,1/yr,,west,21,21,1,1,10,21,  
#Solute Flux,U-235,1/yr,,west,21,21,1,1,10,21,  
#Solute Flux,Np-237,1/yr,,west,21,21,1,1,10,21,  
Solute Flux,Sr-90,1/yr,,west,21,21,1,1,10,21,  
#Solute Flux,Zn-65,1/yr,,west,21,21,1,1,10,21,  
Solute Flux,Eu-155,1/yr,,west,21,21,1,1,10,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,21,21,1,1,17,21,  
#Solute Flux,H-3,1/yr,,west,21,21,1,1,17,21,  
Solute Flux,I-129A,1/yr,,west,21,21,1,1,17,21,  
Solute Flux,I-129B,1/yr,,west,21,21,1,1,17,21,  
#Solute Flux,U-235,1/yr,,west,21,21,1,1,17,21,  
#Solute Flux,Np-237,1/yr,,west,21,21,1,1,17,21,  
Solute Flux,Sr-90,1/yr,,west,21,21,1,1,17,21,  
#Solute Flux,Zn-65,1/yr,,west,21,21,1,1,17,21,  
Solute Flux,Eu-155,1/yr,,west,21,21,1,1,17,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,33,33,1,1,10,21,  
#Solute Flux,H-3,1/yr,,west,33,33,1,1,10,21,  
Solute Flux,I-129A,1/yr,,west,33,33,1,1,10,21,  
Solute Flux,I-129B,1/yr,,west,33,33,1,1,10,21,  
#Solute Flux,U-235,1/yr,,west,33,33,1,1,10,21,  
#Solute Flux,Np-237,1/yr,,west,33,33,1,1,10,21,  
Solute Flux,Sr-90,1/yr,,west,33,33,1,1,10,21,  
#Solute Flux,Zn-65,1/yr,,west,33,33,1,1,10,21,  
Solute Flux,Eu-155,1/yr,,west,33,33,1,1,10,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,33,33,1,1,17,21,  
#Solute Flux,H-3,1/yr,,west,33,33,1,1,17,21,  
Solute Flux,I-129A,1/yr,,west,33,33,1,1,17,21,
```

```
Solute Flux,I-129B,1/yr,,west,33,33,1,1,17,21,  
#Solute Flux,U-235,1/yr,,west,33,33,1,1,17,21,  
#Solute Flux,Np-237,1/yr,,west,33,33,1,1,17,21,  
Solute Flux,Sr-90,1/yr,,west,33,33,1,1,17,21,  
#Solute Flux,Zn-65,1/yr,,west,33,33,1,1,17,21,  
Solute Flux,Eu-155,1/yr,,west,33,33,1,1,17,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,41,41,1,1,10,21,  
#Solute Flux,H-3,1/yr,,west,41,41,1,1,10,21,  
Solute Flux,I-129A,1/yr,,west,41,41,1,1,10,21,  
Solute Flux,I-129B,1/yr,,west,41,41,1,1,10,21,  
#Solute Flux,U-235,1/yr,,west,41,41,1,1,10,21,  
#Solute Flux,Np-237,1/yr,,west,41,41,1,1,10,21,  
Solute Flux,Sr-90,1/yr,,west,41,41,1,1,10,21,  
#Solute Flux,Zn-65,1/yr,,west,41,41,1,1,10,21,  
Solute Flux,Eu-155,1/yr,,west,41,41,1,1,10,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,41,41,1,1,17,21,  
#Solute Flux,H-3,1/yr,,west,41,41,1,1,17,21,  
Solute Flux,I-129A,1/yr,,west,41,41,1,1,17,21,  
Solute Flux,I-129B,1/yr,,west,41,41,1,1,17,21,  
#Solute Flux,U-235,1/yr,,west,41,41,1,1,17,21,  
#Solute Flux,Np-237,1/yr,,west,41,41,1,1,17,21,  
Solute Flux,Sr-90,1/yr,,west,41,41,1,1,17,21,  
#Solute Flux,Zn-65,1/yr,,west,41,41,1,1,17,21,  
Solute Flux,Eu-155,1/yr,,west,41,41,1,1,17,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,58,58,1,1,10,21,  
#Solute Flux,H-3,1/yr,,west,58,58,1,1,10,21,  
Solute Flux,I-129A,1/yr,,west,58,58,1,1,10,21,  
Solute Flux,I-129B,1/yr,,west,58,58,1,1,10,21,  
#Solute Flux,U-235,1/yr,,west,58,58,1,1,10,21,  
#Solute Flux,Np-237,1/yr,,west,58,58,1,1,10,21,  
Solute Flux,Sr-90,1/yr,,west,58,58,1,1,10,21,  
#Solute Flux,Zn-65,1/yr,,west,58,58,1,1,10,21,  
Solute Flux,Eu-155,1/yr,,west,58,58,1,1,10,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,58,58,1,1,17,21,  
#Solute Flux,H-3,1/yr,,west,58,58,1,1,17,21,  
Solute Flux,I-129A,1/yr,,west,58,58,1,1,17,21,  
Solute Flux,I-129B,1/yr,,west,58,58,1,1,17,21,  
#Solute Flux,U-235,1/yr,,west,58,58,1,1,17,21,  
#Solute Flux,Np-237,1/yr,,west,58,58,1,1,17,21,  
Solute Flux,Sr-90,1/yr,,west,58,58,1,1,17,21,  
#Solute Flux,Zn-65,1/yr,,west,58,58,1,1,17,21,  
Solute Flux,Eu-155,1/yr,,west,58,58,1,1,17,21,  
#  
~Output Control Card  
48,  
21,1,10,  
21,1,11,  
21,1,12,  
21,1,13,  
21,1,14,  
21,1,15,  
21,1,16,  
21,1,17,
```

21,1,18,  
21,1,19,  
21,1,20,  
21,1,21,  
33,1,10,  
33,1,11,  
33,1,12,  
33,1,13,  
33,1,14,  
33,1,15,  
33,1,16,  
33,1,17,  
33,1,18,  
33,1,19,  
33,1,20,  
33,1,21,  
41,1,10,  
41,1,11,  
41,1,12,  
41,1,13,  
41,1,14,  
41,1,15,  
41,1,16,  
41,1,17,  
41,1,18,  
41,1,19,  
41,1,20,  
41,1,21,  
58,1,10,  
58,1,11,  
58,1,12,  
58,1,13,  
58,1,14,  
58,1,15,  
58,1,16,  
58,1,17,  
58,1,18,  
58,1,19,  
58,1,20,  
58,1,21,  
1,1,yr,m,8,8,8,  
8,  
aqueous saturation,,  
aqueous pressure,Pa,  
aqueous moisture content,,  
znc aqueous vol,m/yr,  
solute aqueous concentration,I-129A,,  
solute aqueous concentration,I-129B,,  
solute aqueous concentration,Sr-90,,  
solute aqueous concentration,Eu-155,,  
12,  
#1,yr,  
10,yr,  
100,yr,  
200,yr,  
500,yr,  
1000,yr,

1200, yr,  
1500, yr,  
2000, yr,  
#2500, yr,  
5000, yr,  
10000, yr,  
#20000, yr,  
50000, yr,  
100000, yr,  
#200000, yr,  
8,  
aqueous saturation,,  
aqueous pressure, Pa,  
aqueous moisture content,,  
znc aqueous vol, m/yr,  
solute aqueous concentration, I-129A,,  
solute aqueous concentration, I-129B,,  
solute aqueous concentration, Sr-90,,  
solute aqueous concentration, Eu-155,,  
rock/soil type,,

## E.5. Design Recharge, Surrogates 1 – 4 Input, Part A

~Simulation Title Card

1,  
B Pond Lengthwise Cross Section,  
WJ McMahon,  
CH2M Hill Hanford,  
July 23 2001,  
10:00 AM PDT,  
3,  
This input file is the contaminant transport run for the INEEL ICDF simulation  
This construction uses the geology developed by Pete Martian  
The input parameters are based on PM reports

~Solution Control Card

Restart,restart,  
Water w/ Solute Transport,  
9,  
0,day,20,yr,0.0007,yr,0.02,yr,1.25,8,1.e-6,  
20,yr,50,yr,0.02,yr,0.05,yr,1.25,8,1.e-6,  
50,yr,100,yr,0.05,yr,0.10,yr,1.25,8,1.e-6,  
100,yr,500,yr,0.10,yr,0.50,yr,1.25,8,1.e-6,  
500,yr,1000,yr,0.50,yr,2,yr,1.25,8,1.e-6,  
1000,yr,5000,yr,2,yr,10,yr,1.25,8,1.e-6,  
5000,yr,10000,yr,10,yr,100,yr,1.25,8,1.e-6,  
10000,yr,100000,yr,100,yr,1000,yr,1.25,8,1.e-6,  
100000,yr,1000000,yr,1000,yr,10000,yr,1.25,8,1.e-6,  
8000,  
0,

~Grid Card

cartesian,  
60,1,98,  
# X Dimensions::160 m ICDF cell Total X Dimension 320 m  
0.,m,6@15,m,5@10,m,2@5,m,2@5,m,  
#20 m to screening model compliance point,  
2@5,m,1@4.,m,1@3.,m,1@2.,m,1@1.,m,  
#190 feet (or 58 m) to edge of landfill cap (less 20 m above)  
2@2.,m,1@3,m,1@4.,m,2@6.,m,1@4.,m,2@3.,m,2@2,m,1@1.,m,  
#190 feet (or 58 m) plus 20 m (less 58 m above)  
2@2.,m,1@3,m,1@4.,m,2@3.,m,1@2,m,1@1.,m,  
#190 feet (or 58 m) plus 100 m (less 78 m above)  
2@2.,m,1@3,m,2@4.,m,2@5.,m,5@8.,m,1@5.,m,1@4.,m,1@3.,m,1@2,m,1@1.,m,  
#One grid block to move last observation point off of boundary  
2@1.,m,  
# Y Dimensions (Y dimension not used)  
0.,m,1.,m,  
# Z Dimensions  
#Basalt Aquifer (Total = 76 m, Begin and End Lower 61 m) 9 Rows (Ignore 0)  
0.,m,2@12.,m,2@8.,m,2@6.,m,1@4.,m,1@3.,m,1@2.,m,  
#Basalt Aquifer Begin First 9 m of Upper 15 m 6 Rows  
6@1.5,m,  
#Basalt Aquifer Begin and End Upper 6 m  
# (7 m or 22 ft-note 6 m saturated and 1 m above water table) 6 Rows  
1@1,m,1@1,m,1@1,m,1@1,m,1@2,m,

```
#Basalt (16.98 m or 57 ft-note that 1 m added to aquifer layer, 17.98 m = 59
ft)
# 7 Rows
1@2,m,1@2.32,m,1@2.75,m,1@3.25,m,1@3,m,1@2.15,m,1@1.51,m,
#Sedimentary Interbed (7.01 m or 23 ft) 4 Rows
1@1.51,m,1@2,m,1@2,m,1@1.5,m,
#Basalt (39.93 m or 131 ft) 13 Rows
1@1.5,m,1@2,m,1@3,m,1@4,m,1@4,m,1@4.5,m,1@4.5,m,1@4,m,1@3,m,1@2.4,m,
1@1.81,m,1@1.22,m,
#Sedimentary Interbed (4.88 m or 16 ft) 4 Rows
1@1.22,m,1@1.22,m,1@1.22,m,1@1.22,m,
#Basalt (23.47 m or 77 ft) 9 Rows
1@1.22,m,1@2,m,1@3,m,1@3.5,m,1@3.75,m,1@3.5,m,1@3,m,1@2,m,1@1.5,m,
#Sedimentary Interbed (11.89 m or 39 ft) 6 Rows
1@1.5,m,1@1.94,m,1@2.45,m,1@2.45,m,1@2.15,m,1@1.4,m,
#Basalt (26.52 m or 87 ft) 13 Rows
1@1.4,m,1@2,m,1@2,m,1@3,m,1@5,m,1@5,m,1@3,m,1@1.57,m,1@1.2,m,1@1,m,1@0.6,m,
1@0.45,m,1@0.3,m,
#Alluvium changed from 9 to 5 feet (1.52 m or 5 ft) 4 Rows
1@0.30,m,1@0.46,m,1@0.46,m,1@0.30,m,
#Clay Liner (0.91 m or 3 ft) 3 Rows
1@0.30,m,1@0.31,m,1@0.30,m,
#Operations Layer (0.91 m or 3 ft) 3 Rows
1@0.30,m,1@0.31,m,1@0.30,m,
#Waste (10.40 m or 34 ft adjusted to 12.56 m to account for cube vs
trapezoid)
# 11 Rows
1@0.5,m,1@0.5,m,1@1,m,1@1,m,1@1.64,m,1@1.64,m,1@1.64,m,1@1.64,m,1@1,m,1@1,m,1
@1,m,
```

~Rock/Soil Zonation Card

```
14,
#Lower 61 m of Basalt Aquifer
Basalt Aquifer,1,60,1,1,1,9,
#Begin First 9 m of Upper 15 m of Basalt Aquifer
Basalt Aquifer,1,60,1,1,10,15,
#Upper 6 m of Basalt Aquifer
Basalt Aquifer,1,60,1,1,16,21,
#Lowest Vadose Basalt Layer
Basalt,1,60,1,1,22,28,
Interbed,1,60,1,1,29,32,
Basalt,1,60,1,1,33,45,
Interbed,1,60,1,1,46,49,
Basalt,1,60,1,1,50,58,
Interbed,1,60,1,1,59,64,
Basalt,1,60,1,1,65,77,
Alluvium,1,60,1,1,78,81,
Clay,1,60,1,1,82,84,
Operation Gravelly Sand,1,60,1,1,85,87,
Waste Gravelly Sand,1,60,1,1,88,98,
```

~Inactive Nodes Card

```
#Integer,
1,
16,60,1,1,22,98,
```

~Mechanical Properties Card

```
#Particle density = 2650 kg/m^3 except for clay and old alluvium
#Subgrade, attenuation barrier, and drain rock used in earlier models but
#not used here
#Basalt and interbed properties from P. Martian Screening Model
Basalt Aquifer,,,0.06,0.06,,,Millington and Quirk,
Interbed,,,0.487,0.487,,,Millington and Quirk,
Basalt,,,0.05,0.05,,,Millington and Quirk,
#
#Old Alluvium characteristics from Geotech report measurements
# sat. moisture content (0.422, 0.426); dry bulk density (1.60, 1.64 g/cm^3)
# particle density = 1.62 g/cm^3/(1-0.424) = 2.8125 g/cm^3
Alluvium,2812.5,kg/m^3,0.424,0.424,,,Millington and Quirk,
#Attenuation Barrier,,,0.400,0.400,,,Millington and Quirk,
#Clay characteristics per discussion with J. Dehner
Clay,2600,kg/m^3,0.390,0.390,,,Millington and Quirk,
#Drain Rock,,,0.400,0.400,,,Millington and Quirk,
Operation Gravelly Sand,,,0.275,0.275,,,Millington and Quirk,
#Operation Gravelly Sand dry bulk density = 120 lb/ft^3 (per J. Dehner)
#120 lb/ft^3*0.4536 kg/lb*1 ft^3/(0.3048 m/ft)^3 = 1922.25 kg/m^3
#Porosity Operation Gravelly Sand = 1-(1922.25/2650)= 0.275
Waste Gravelly Sand,,,0.266,0.266,,,Millington and Quirk,
#Waste Gravelly Sand dry bulk density = 121.5 lb/ft^3 (per J. Dehner)
#121.5 lb/ft^3*0.4536 kg/lb*1 ft^3/(0.3048 m)^3 = 1946.28 kg/m^3
#Porosity Waste Gravelly Sand = 1-(1946.28/2650)= 0.266
```

```
~Hydraulic Properties Card
#Properties from P. Martian Screening Model except old alluvium
Basalt Aquifer,9.00e+01,darcy,,,3.00e-01,darcy,
Interbed,6.7e-5,hc:cm/s,,,6.7e-5,hc:cm/s,
Basalt,9.00e+01,darcy,,,3.00e-01,darcy,
#Old Alluvium characteristics from Geotech report measurements
# sat. hydraulic conductivity (1.2e-07 cm/s, 6.2e-08 cm/s, 7.1e-08 cm/s)
Alluvium,1.2e-07,hc:cm/s,,,1.2e-07,hc:cm/s,
#Subgrade,1e-04,hc:cm/s,,,1e-04,hc:cm/s,
#Attenuation Barrier,1e-07,hc:cm/s,,,1e-07,hc:cm/s,
Clay,1e-07,hc:cm/s,,,1e-07,hc:cm/s,
#Drain Rock,3.0e-01,hc:cm/s,,,3.0e-01,hc:cm/s,
Operation Gravelly Sand,1e-04,hc:cm/s,,,1e-04,hc:cm/s,
Waste Gravelly Sand,1e-03,hc:cm/s,,,1e-03,hc:cm/s,
```

```
~Saturation Function Card
#Parameters from P. Martian Screening Model except old alluvium
#alpha, n, theta R, m
#m only specified for basalts, otherwise default m = 1 - 1/n
Basalt Aquifer,Nonhysteretic van Genuchten,4.0,1/m,4.5,0.0002,0.7777778,
Interbed,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.142,,,
Basalt,Nonhysteretic van Genuchten,4.0,1/m,4.5,0.0002,0.7777778,
#Old Alluvium characteristics from RETC fitting of Geotech report
measurements
Alluvium,Nonhysteretic van Genuchten,0.595,1/m,1.09,0.142,,,
#Subgrade,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.142,,,
#Attenuation Barrier,Nonhysteretic van Genuchten,0.800,1/m,1.090,0.07,,,
Clay,Nonhysteretic van Genuchten,0.800,1/m,1.109,0.07,,,
#Drain Rock,Nonhysteretic van Genuchten,493,1/m,2.190,0.005,,,
Operation Gravelly Sand,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.083,,,
Waste Gravelly Sand,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.072,,,
#
```

```
~Aqueous Relative Permeability Card
#m only specified for basalts, otherwise default m = 1 - 1/n
Basalt Aquifer,Mualem,1.9,
Interbed,Mualem.,
Basalt,Mualem,1.9,
Alluvium,Mualem.,
#Subgrade,Mualem.,
#Attenuation Barrier,Mualem.,
Clay,Mualem.,
#Drain Rock,Mualem.,
Operation Gravelly Sand,Mualem.,
Waste Gravelly Sand,Mualem.,
#
~Solute/Fluid Interactions Card
4,
H-3,conventional,1.0e-09,m^2/s,noncontinuous,,,,
I-129,conventional,1.0e-09,m^2/s,noncontinuous,,,,
Tc-99,conventional,1.0e-09,m^2/s,noncontinuous,,,,
U-235,conventional,1.0e-09,m^2/s,noncontinuous,,,,
#Np-237,conventional,1.0e-09,m^2/s,noncontinuous,,,,
#Sr-90,conventional,1.0e-09,m^2/s,noncontinuous,,,,
#Zn-65,conventional,1.0e-09,m^2/s,noncontinuous,,,,
#Eu-155,conventional,1.0e-09,m^2/s,noncontinuous,,,,
0,
#
~Solute/Porous Media Interaction Card
Basalt Aquifer,6.0,m,3.0,m,
H-3,0.0,cm^3/g,
I-129,0.0,cm^3/g,
Tc-99,0.008,cm^3/g,
U-235,0.24,cm^3/g,
#Np-237,0.32,cm^3/g,
#Sr-90,0.48,cm^3/g,
#Zn-65,0.64,cm^3/g,
#Eu-155,314,cm^3/g,
#
Interbed,5.0,m,0,m,
H-3,0.0,cm^3/g,
I-129,0.0,cm^3/g,
Tc-99,0.2,cm^3/g,
U-235,6.0,cm^3/g,
#Np-237,8.0,cm^3/g,
#Sr-90,24.0,cm^3/g,
#Zn-65,16.0,cm^3/g,
#Eu-155,314,cm^3/g,
#
Basalt,5.0,m,0,m,
H-3,0.0,cm^3/g,
I-129,0.0,cm^3/g,
Tc-99,0.0,cm^3/g,
U-235,0.0,cm^3/g,
#Np-237,0.0,cm^3/g,
#Sr-90,0.0,cm^3/g,
#Zn-65,0.0,cm^3/g,
#Eu-155,314,cm^3/g,
#
#Subgrade,5.0,m,0,m,
```

```
#  
Alluvium,5.0,m,0,m,  
H-3,0.0,cm^3/g,  
I-129,0.0,cm^3/g,  
Tc-99,0.2,cm^3/g,  
U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,  
#Sr-90,24.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
#Eu-155,314,cm^3/g,  
#  
#Attenuation Barrier,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
#I-129,1.0,cm^3/g,  
#Tc-99,1.0,cm^3/g,  
#U-235,63.0,cm^3/g,  
#Np-237,55.0,cm^3/g,  
#Sr-90,200.0,cm^3/g,  
#Zn-65,2400.0,cm^3/g,  
#Eu-155,314,cm^3/g,  
#  
Clay,5.0,m,0,m,  
H-3,0.0,cm^3/g,  
I-129,1.0,cm^3/g,  
Tc-99,1.0,cm^3/g,  
U-235,63.0,cm^3/g,  
#Np-237,55.0,cm^3/g,  
#Sr-90,200.0,cm^3/g,  
#Zn-65,2400.0,cm^3/g,  
#Eu-155,314,cm^3/g,  
#  
#Drain Rock,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
#I-129,0.0,cm^3/g,  
#Tc-99,0.2,cm^3/g,  
#U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,  
#Sr-90,24.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
#Eu-155,314,cm^3/g,  
#  
Operation Gravelly Sand,5.0,m,0,m,  
H-3,0.0,cm^3/g,  
I-129,0.0,cm^3/g,  
Tc-99,0.2,cm^3/g,  
U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,  
#Sr-90,24.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
#Eu-155,314,cm^3/g,  
#  
Waste Gravelly Sand,5.0,m,0,m,  
H-3,0.0,cm^3/g,  
I-129,0.0,cm^3/g,  
Tc-99,0.2,cm^3/g,  
U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,
```

```
#Sr-90,12.0,cm^3/g,
#Zn-65,16.0,cm^3/g,
#Eu-155,314,cm^3/g,
#
~Initial Conditions Card
Gas Pressure,Aqueous Pressure,
9,
Aqueous Pressure,,,,,,,1,60,1,1,1,98,
Solute Volume Overwrite,H-3,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,
Solute Volume Overwrite,I-129,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,
Solute Volume Overwrite,Tc-99,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,
Solute Volume Overwrite,U-235,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,
#Solute Volume Overwrite,Np-237,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,
#Solute Volume Overwrite,Sr-90,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,
#Solute Volume Overwrite,Zn-65,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,
#Solute Volume Overwrite,Eu-155,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,
#
Solute Volume Overwrite,H-3,1946.28,1/m^3,0,,0,,0,,1,15,1,1,88,98,
Solute Volume Overwrite,I-129,1946.28,1/m^3,0,,0,,0,,1,15,1,1,88,98,
Solute Volume Overwrite,Tc-99,1946.28,1/m^3,0,,0,,0,,1,15,1,1,88,98,
Solute Volume Overwrite,U-235,1946.28,1/m^3,0,,0,,0,,1,15,1,1,88,98,
#Solute Volume Overwrite,Np-237,1946.28,1/m^3,0,,0,,0,,1,15,1,1,88,98,
#Solute Volume Overwrite,Sr-90,1946.28,1/m^3,0,,0,,0,,1,15,1,1,88,98,
#Solute Volume Overwrite,Zn-65,1946.28,1/m^3,0,,0,,0,,1,15,1,1,88,98,
#Solute Volume Overwrite,Eu-155,1946.28,1/m^3,0,,0,,0,,1,15,1,1,88,98,

~Boundary Conditions Card
4,
#
top,neumann,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,
#0.0001 m/yr * 1.74 ICDF Recharge Ratio = 0.000174 m/yr
1,15,1,1,98,98,1,
0,day,-0.000174,m/yr,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,
#0,1/m^3,0,1/m^3,
#0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,
#
west,neumann,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,
1,1,1,1,20,1,
0,day,0.06,m/day,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,
#0,1/m^3,0,1/m^3,
#0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,
#
west,neumann,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,
1,1,1,1,21,1,
0,day,0.03,m/day,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,
#0,1/m^3,0,1/m^3,
#0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,
#
east,hydraulic gradient,outflow,outflow,outflow,outflow,
#Hold head constant to keep h ~ 5 m at compliance point
60,60,1,1,1,21,1,
```

```
0,day,786871.34,Pa,,,,,,,,,,  
#  
~Surface Flux Card  
50,  
Aqueous Volumetric Flux,m^3/yr,m^3,bottom,1,15,1,1,82,82,  
Solute Flux,H-3,1/yr,,bottom,1,15,1,1,82,82,  
Solute Flux,I-129,1/yr,,bottom,1,15,1,1,82,82,  
Solute Flux,Tc-99,1/yr,,bottom,1,15,1,1,82,82,  
Solute Flux,U-235,1/yr,,bottom,1,15,1,1,82,82,  
#Solute Flux,Np-237,1/yr,,bottom,1,15,1,1,82,82,  
#Solute Flux,Sr-90,1/yr,,bottom,1,15,1,1,82,82,  
#Solute Flux,Zn-65,1/yr,,bottom,1,15,1,1,82,82,  
#Solute Flux,Eu-155,1/yr,,bottom,1,15,1,1,82,82,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,bottom,1,15,1,1,22,22,  
Solute Flux,H-3,1/yr,,bottom,1,15,1,1,22,22,  
Solute Flux,I-129,1/yr,,bottom,1,15,1,1,22,22,  
Solute Flux,Tc-99,1/yr,,bottom,1,15,1,1,22,22,  
Solute Flux,U-235,1/yr,,bottom,1,15,1,1,22,22,  
#Solute Flux,Np-237,1/yr,,bottom,1,15,1,1,22,22,  
#Solute Flux,Sr-90,1/yr,,bottom,1,15,1,1,22,22,  
#Solute Flux,Zn-65,1/yr,,bottom,1,15,1,1,22,22,  
#Solute Flux,Eu-155,1/yr,,bottom,1,15,1,1,22,22,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,21,21,1,1,10,21,  
Solute Flux,H-3,1/yr,,west,21,21,1,1,10,21,  
Solute Flux,I-129,1/yr,,west,21,21,1,1,10,21,  
Solute Flux,Tc-99,1/yr,,west,21,21,1,1,10,21,  
Solute Flux,U-235,1/yr,,west,21,21,1,1,10,21,  
#Solute Flux,Np-237,1/yr,,west,21,21,1,1,10,21,  
#Solute Flux,Sr-90,1/yr,,west,21,21,1,1,10,21,  
#Solute Flux,Zn-65,1/yr,,west,21,21,1,1,10,21,  
#Solute Flux,Eu-155,1/yr,,west,21,21,1,1,10,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,21,21,1,1,17,21,  
Solute Flux,H-3,1/yr,,west,21,21,1,1,17,21,  
Solute Flux,I-129,1/yr,,west,21,21,1,1,17,21,  
Solute Flux,Tc-99,1/yr,,west,21,21,1,1,17,21,  
Solute Flux,U-235,1/yr,,west,21,21,1,1,17,21,  
#Solute Flux,Np-237,1/yr,,west,21,21,1,1,17,21,  
#Solute Flux,Sr-90,1/yr,,west,21,21,1,1,17,21,  
#Solute Flux,Zn-65,1/yr,,west,21,21,1,1,17,21,  
#Solute Flux,Eu-155,1/yr,,west,21,21,1,1,17,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,33,33,1,1,10,21,  
Solute Flux,H-3,1/yr,,west,33,33,1,1,10,21,  
Solute Flux,I-129,1/yr,,west,33,33,1,1,10,21,  
Solute Flux,Tc-99,1/yr,,west,33,33,1,1,10,21,  
Solute Flux,U-235,1/yr,,west,33,33,1,1,10,21,  
#Solute Flux,Np-237,1/yr,,west,33,33,1,1,10,21,  
#Solute Flux,Sr-90,1/yr,,west,33,33,1,1,10,21,  
#Solute Flux,Zn-65,1/yr,,west,33,33,1,1,10,21,  
#Solute Flux,Eu-155,1/yr,,west,33,33,1,1,10,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,33,33,1,1,17,21,  
Solute Flux,H-3,1/yr,,west,33,33,1,1,17,21,  
Solute Flux,I-129,1/yr,,west,33,33,1,1,17,21,
```

```
Solute Flux,Tc-99,1/yr,,west,33,33,1,1,17,21,  
Solute Flux,U-235,1/yr,,west,33,33,1,1,17,21,  
#Solute Flux,Np-237,1/yr,,west,33,33,1,1,17,21,  
#Solute Flux,Sr-90,1/yr,,west,33,33,1,1,17,21,  
#Solute Flux,Zn-65,1/yr,,west,33,33,1,1,17,21,  
#Solute Flux,Eu-155,1/yr,,west,33,33,1,1,17,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,41,41,1,1,10,21,  
Solute Flux,H-3,1/yr,,west,41,41,1,1,10,21,  
Solute Flux,I-129,1/yr,,west,41,41,1,1,10,21,  
Solute Flux,Tc-99,1/yr,,west,41,41,1,1,10,21,  
Solute Flux,U-235,1/yr,,west,41,41,1,1,10,21,  
#Solute Flux,Np-237,1/yr,,west,41,41,1,1,10,21,  
#Solute Flux,Sr-90,1/yr,,west,41,41,1,1,10,21,  
#Solute Flux,Zn-65,1/yr,,west,41,41,1,1,10,21,  
#Solute Flux,Eu-155,1/yr,,west,41,41,1,1,10,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,41,41,1,1,17,21,  
Solute Flux,H-3,1/yr,,west,41,41,1,1,17,21,  
Solute Flux,I-129,1/yr,,west,41,41,1,1,17,21,  
Solute Flux,Tc-99,1/yr,,west,41,41,1,1,17,21,  
Solute Flux,U-235,1/yr,,west,41,41,1,1,17,21,  
#Solute Flux,Np-237,1/yr,,west,41,41,1,1,17,21,  
#Solute Flux,Sr-90,1/yr,,west,41,41,1,1,17,21,  
#Solute Flux,Zn-65,1/yr,,west,41,41,1,1,17,21,  
#Solute Flux,Eu-155,1/yr,,west,41,41,1,1,17,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,58,58,1,1,10,21,  
Solute Flux,H-3,1/yr,,west,58,58,1,1,10,21,  
Solute Flux,I-129,1/yr,,west,58,58,1,1,10,21,  
Solute Flux,Tc-99,1/yr,,west,58,58,1,1,10,21,  
Solute Flux,U-235,1/yr,,west,58,58,1,1,10,21,  
#Solute Flux,Np-237,1/yr,,west,58,58,1,1,10,21,  
#Solute Flux,Sr-90,1/yr,,west,58,58,1,1,10,21,  
#Solute Flux,Zn-65,1/yr,,west,58,58,1,1,10,21,  
#Solute Flux,Eu-155,1/yr,,west,58,58,1,1,10,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,58,58,1,1,17,21,  
Solute Flux,H-3,1/yr,,west,58,58,1,1,17,21,  
Solute Flux,I-129,1/yr,,west,58,58,1,1,17,21,  
Solute Flux,Tc-99,1/yr,,west,58,58,1,1,17,21,  
Solute Flux,U-235,1/yr,,west,58,58,1,1,17,21,  
#Solute Flux,Np-237,1/yr,,west,58,58,1,1,17,21,  
#Solute Flux,Sr-90,1/yr,,west,58,58,1,1,17,21,  
#Solute Flux,Zn-65,1/yr,,west,58,58,1,1,17,21,  
#Solute Flux,Eu-155,1/yr,,west,58,58,1,1,17,21,  
#  
~Output Control Card  
48,  
21,1,10,  
21,1,11,  
21,1,12,  
21,1,13,  
21,1,14,  
21,1,15,  
21,1,16,  
21,1,17,
```

21,1,18,  
21,1,19,  
21,1,20,  
21,1,21,  
33,1,10,  
33,1,11,  
33,1,12,  
33,1,13,  
33,1,14,  
33,1,15,  
33,1,16,  
33,1,17,  
33,1,18,  
33,1,19,  
33,1,20,  
33,1,21,  
41,1,10,  
41,1,11,  
41,1,12,  
41,1,13,  
41,1,14,  
41,1,15,  
41,1,16,  
41,1,17,  
41,1,18,  
41,1,19,  
41,1,20,  
41,1,21,  
58,1,10,  
58,1,11,  
58,1,12,  
58,1,13,  
58,1,14,  
58,1,15,  
58,1,16,  
58,1,17,  
58,1,18,  
58,1,19,  
58,1,20,  
58,1,21,  
1,1,yr,m,8,8,8,  
8,  
aqueous saturation,,  
aqueous pressure,Pa,  
aqueous moisture content,,  
znc aqueous vol,m/yr,  
solute aqueous concentration,H-3,,  
solute aqueous concentration,I-129,,  
solute aqueous concentration,Tc-99,,  
solute aqueous concentration,U-235,,  
12,  
#1,yr,  
10,yr,  
100,yr,  
200,yr,  
500,yr,  
1000,yr,

1200, yr,  
1500, yr,  
2000, yr,  
#2500, yr,  
5000, yr,  
10000, yr,  
#20000, yr,  
50000, yr,  
100000, yr,  
#200000, yr,  
8,  
aqueous saturation,,  
aqueous pressure, Pa,  
aqueous moisture content,,  
znc aqueous vol, m/yr,  
solute aqueous concentration, H-3,,  
solute aqueous concentration, I-129,,  
solute aqueous concentration, Tc-99,,  
solute aqueous concentration, U-235,,  
rock/soil type,,

## E.6. Design Recharge, Surrogates 1 – 4 Input, Part B

~Simulation Title Card

1,  
INEEL Lengthwise Cross Section,  
WJ McMahon,  
CH2M Hill Hanford,  
November 29 2001,  
5:00 PM PDT,  
3,  
This input file is the contaminant transport run for the INEEL ICDF simulation  
This construction uses the geology developed by Pete Martian  
The input parameters are based on PM reports

~Solution Control Card

Restart,restart,  
Water w/ Solute Transport,  
2,  
0,day,20,yr,0.0007,yr,0.02,yr,1.25,8,1.e-6,  
20,yr,30,yr,0.02,yr,0.05,yr,1.25,8,1.e-6,  
8000,  
0,

~Grid Card

cartesian,  
60,1,98,  
# X Dimensions::160 m ICDF cell Total X Dimension 320 m  
0.,m,6@15,m,5@10,m,2@5,m,2@5,m,  
#20 m to screening model compliance point,  
2@5,m,1@4.,m,1@3.,m,1@2.,m,1@1.,m,  
#190 feet (or 58 m) to edge of landfill cap (less 20 m above)  
2@2.,m,1@3,m,1@4.,m,2@6.,m,1@4.,m,2@3.,m,2@2,m,1@1.,m,  
#190 feet (or 58 m) plus 20 m (less 58 m above)  
2@2.,m,1@3,m,1@4.,m,2@3.,m,1@2,m,1@1.,m,  
#190 feet (or 58 m) plus 100 m (less 78 m above)  
2@2.,m,1@3,m,2@4.,m,2@5.,m,5@8.,m,1@5.,m,1@4.,m,1@3.,m,1@2,m,1@1.,m,  
#One grid block to move last observation point off of boundary  
2@1.,m,  
# Y Dimensions (Y dimension not used)  
0.,m,1.,m,  
# Z Dimensions  
#Basalt Aquifer (Total = 76 m, Begin and End Lower 61 m) 9 Rows (Ignore 0)  
0.,m,2@12.,m,2@8.,m,2@6.,m,1@4.,m,1@3.,m,1@2.,m,  
#Basalt Aquifer Begin First 9 m of Upper 15 m 6 Rows  
6@1.5,m,  
#Basalt Aquifer Begin and End Upper 6 m  
# (7 m or 22 ft-note 6 m saturated and 1 m above water table) 6 Rows  
1@1,m,1@1,m,1@1,m,1@1,m,1@2,m,  
#Basalt (16.98 m or 57 ft-note that 1 m added to aquifer layer, 17.98 m = 59 ft)  
# 7 Rows  
1@2,m,1@2.32,m,1@2.75,m,1@3.25,m,1@3,m,1@2.15,m,1@1.51,m,  
#Sedimentary Interbed (7.01 m or 23 ft) 4 Rows  
1@1.51,m,1@2,m,1@2,m,1@1.5,m,  
#Basalt (39.93 m or 131 ft) 13 Rows

1@1.5,m,1@2,m,1@3,m,1@4,m,1@4,m,1@4.5,m,1@4.5,m,1@4,m,1@4,m,1@3,m,1@2.4,m,  
1@1.81,m,1@1.22,m,  
#Sedimentary Interbed (4.88 m or 16 ft) 4 Rows  
1@1.22,m,1@1.22,m,1@1.22,m,1@1.22,m,  
#Basalt (23.47 m or 77 ft) 9 Rows  
1@1.22,m,1@2,m,1@3,m,1@3.5,m,1@3.75,m,1@3.5,m,1@3,m,1@2,m,1@1.5,m,  
#Sedimentary Interbed (11.89 m or 39 ft) 6 Rows  
1@1.5,m,1@1.94,m,1@2.45,m,1@2.45,m,1@2.15,m,1@1.4,m,  
#Basalt (26.52 m or 87 ft) 13 Rows  
1@1.4,m,1@2,m,1@2,m,1@3,m,1@5,m,1@3,m,1@1.57,m,1@1.2,m,1@1,m,1@0.6,m,  
1@0.45,m,1@0.3,m,  
#Alluvium changed from 9 to 5 feet (1.52 m or 5 ft) 4 Rows  
1@0.30,m,1@0.46,m,1@0.46,m,1@0.30,m,  
#Clay Liner (0.91 m or 3 ft) 3 Rows  
1@0.30,m,1@0.31,m,1@0.30,m,  
#Operations Layer (0.91 m or 3 ft) 3 Rows  
1@0.30,m,1@0.31,m,1@0.30,m,  
#Waste (10.40 m or 34 ft adjusted to 12.56 m to account for cube vs  
trapezoid)  
# 11 Rows  
1@0.5,m,1@0.5,m,1@1,m,1@1,m,1@1.64,m,1@1.64,m,1@1.64,m,1@1,m,1@1,m,1  
@1,m,

~Rock/Soil Zonation Card

14,  
#Lower 61 m of Basalt Aquifer  
Basalt Aquifer,1,60,1,1,1,9,  
#Begin First 9 m of Upper 15 m of Basalt Aquifer  
Basalt Aquifer,1,60,1,1,10,15,  
#Upper 6 m of Basalt Aquifer  
Basalt Aquifer,1,60,1,1,16,21,  
#Lowest Vadose Basalt Layer  
Basalt,1,60,1,1,22,28,  
Interbed,1,60,1,1,29,32,  
Basalt,1,60,1,1,33,45,  
Interbed,1,60,1,1,46,49,  
Basalt,1,60,1,1,50,58,  
Interbed,1,60,1,1,59,64,  
Basalt,1,60,1,1,65,77,  
Alluvium,1,60,1,1,78,81,  
Clay,1,60,1,1,82,84,  
Operation Gravelly Sand,1,60,1,1,85,87,  
Waste Gravelly Sand,1,60,1,1,88,98,

~Inactive Nodes Card

#Integer,  
2,  
16,60,1,1,1,98,  
1,15,1,1,1,84,

~Mechanical Properties Card

#Particle density = 2650 kg/m<sup>3</sup> except for clay and old alluvium  
#Subgrade, attenuation barrier, and drain rock used in earlier models but  
#not used here  
#Basalt and interbed properties from P. Martian Screening Model  
Basalt Aquifer,,,0.06,0.06,,,Millington and Quirk,  
Interbed,,,0.487,0.487,,,Millington and Quirk,

```
Basalt,,,0.05,0.05,,,Millington and Quirk,  
#  
#Old Alluvium characteristics from Geotech report measurements  
# sat. moisture content (0.422, 0.426); dry bulk density (1.60, 1.64 g/cm^3)  
# particle density = 1.62 g/cm^3/(1-0.424) = 2.8125 g/cm^3  
Alluvium,2812.5,kg/m^3,0.424,0.424,,,Millington and Quirk,  
#Attenuation Barrier,,,0.400,0.400,,,Millington and Quirk,  
#Clay characteristics per discussion with J. Dehner  
Clay,2600,kg/m^3,0.390,0.390,,,Millington and Quirk,  
#Drain Rock,,,0.400,0.400,,,Millington and Quirk,  
Operation Gravelly Sand,,,0.275,0.275,,,Millington and Quirk,  
#Operation Gravelly Sand dry bulk density = 120 lb/ft^3 (per J. Dehner)  
#120 lb/ft^3*0.4536 kg/lb*1 ft^3/(0.3048 m/ft)^3 = 1922.25 kg/m^3  
#Porosity Operation Gravelly Sand = 1-(1922.25/2650)= 0.275  
Waste Gravelly Sand,,,0.266,0.266,,,Millington and Quirk,  
#Waste Gravelly Sand dry bulk density = 121.5 lb/ft^3 (per J. Dehner)  
#121.5 lb/ft^3*0.4536 kg/lb*1 ft^3/(0.3048 m)^3 = 1946.28 kg/m^3  
#Porosity Waste Gravelly Sand = 1-(1946.28/2650)= 0.266
```

~Hydraulic Properties Card

```
#Properties from P. Martian Screening Model except old alluvium  
Basalt Aquifer,9.00e+01,darcy,,,3.00e-01,darcy,  
Interbed,6.7e-5,hc:cm/s,,,6.7e-5,hc:cm/s,  
Basalt,9.00e+01,darcy,,,3.00e-01,darcy,  
#Old Alluvium characteristics from Geotech report measurements  
# sat. hydraulic conductivity (1.2e-07 cm/s, 6.2e-08 cm/s, 7.1e-08 cm/s)  
Alluvium,1.2e-07,hc:cm/s,,,1.2e-07,hc:cm/s,  
#Subgrade,1e-04,hc:cm/s,,,1e-04,hc:cm/s,  
#Attenuation Barrier,1e-07,hc:cm/s,,,1e-07,hc:cm/s,  
Clay,1e-07,hc:cm/s,,,1e-07,hc:cm/s,  
#Drain Rock,3.0e-01,hc:cm/s,,,3.0e-01,hc:cm/s,  
Operation Gravelly Sand,1e-04,hc:cm/s,,,1e-04,hc:cm/s,  
Waste Gravelly Sand,1e-03,hc:cm/s,,,1e-03,hc:cm/s,
```

~Saturation Function Card

```
#Parameters from P. Martian Screening Model except old alluvium  
#alpha, n, theta R, m  
#m only specified for basalts, otherwise default m = 1 - 1/n  
Basalt Aquifer,Nonhysteretic van Genuchten,4.0,1/m,4.5,0.0002,0.7777778,  
Interbed,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.142,,  
Basalt,Nonhysteretic van Genuchten,4.0,1/m,4.5,0.0002,0.7777778,  
#Old Alluvium characteristics from RETC fitting of Geotech report  
measurements  
Alluvium,Nonhysteretic van Genuchten,0.595,1/m,1.09,0.142,,  
#Subgrade,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.142,,  
#Attenuation Barrier,Nonhysteretic van Genuchten,0.800,1/m,1.090,0.07,,  
Clay,Nonhysteretic van Genuchten,0.800,1/m,1.109,0.07,,  
#Drain Rock,Nonhysteretic van Genuchten,493,1/m,2.190,0.005,,  
Operation Gravelly Sand,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.083,,  
Waste Gravelly Sand,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.072,,  
#
```

~Aqueous Relative Permeability Card

```
#m only specified for basalts, otherwise default m = 1 - 1/n  
Basalt Aquifer,Mualem,1.9,  
Interbed,Mualem,,  
Basalt,Mualem,1.9,  
Alluvium,Mualem,,
```

```
#Subgrade,Mualem,,  
#Attenuation Barrier,Mualem,,  
Clay,Mualem,,  
#Drain Rock,Mualem,,  
Operation Gravelly Sand,Mualem,,  
Waste Gravelly Sand,Mualem,,  
#  
~Solute/Fluid Interactions Card  
4,  
H-3,conventional,1.0e-09,m^2/s,noncontinuous,,,  
I-129,conventional,1.0e-09,m^2/s,noncontinuous,,,  
Tc-99,conventional,1.0e-09,m^2/s,noncontinuous,,,  
U-235,conventional,1.0e-09,m^2/s,noncontinuous,,,  
#Np-237,conventional,1.0e-09,m^2/s,noncontinuous,,,  
#Sr-90,conventional,1.0e-09,m^2/s,noncontinuous,,,  
#Zn-65,conventional,1.0e-09,m^2/s,noncontinuous,,,  
#Eu-155,conventional,1.0e-09,m^2/s,noncontinuous,,,  
0,  
#  
~Solute/Porous Media Interaction Card  
Basalt Aquifer,6.0,m,3.0,m,  
H-3,0.0,cm^3/g,  
I-129,0.0,cm^3/g,  
Tc-99,0.008,cm^3/g,  
U-235,0.24,cm^3/g,  
#Np-237,0.32,cm^3/g,  
#Sr-90,0.48,cm^3/g,  
#Zn-65,0.64,cm^3/g,  
#Eu-155,314,cm^3/g,  
#  
Interbed,5.0,m,0,m,  
H-3,0.0,cm^3/g,  
I-129,0.0,cm^3/g,  
Tc-99,0.2,cm^3/g,  
U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,  
#Sr-90,24.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
#Eu-155,340,cm^3/g,  
#  
Basalt,5.0,m,0,m,  
H-3,0.0,cm^3/g,  
I-129,0.0,cm^3/g,  
Tc-99,0.0,cm^3/g,  
U-235,0.0,cm^3/g,  
#Np-237,0.0,cm^3/g,  
#Sr-90,0.0,cm^3/g,  
#Zn-65,0.0,cm^3/g,  
#Eu-155,0.0,cm^3/g,  
#  
#Subgrade,5.0,m,0,m,  
#  
Alluvium,5.0,m,0,m,  
H-3,0.0,cm^3/g,  
I-129,0.0,cm^3/g,  
Tc-99,0.2,cm^3/g,  
U-235,6.0,cm^3/g,
```

```
#Np-237,8.0,cm^3/g,  
#Sr-90,24.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
#Eu-155,340,cm^3/g,  
#  
#Attenuation Barrier,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
#I-129,1.0,cm^3/g,  
#Tc-99,1.0,cm^3/g,  
#U-235,63.0,cm^3/g,  
#Np-237,55.0,cm^3/g,  
#Sr-90,200.0,cm^3/g,  
#Zn-65,2400.0,cm^3/g,  
#Eu-155,340,cm^3/g,  
#  
Clay,5.0,m,0,m,  
H-3,0.0,cm^3/g,  
I-129,1.0,cm^3/g,  
Tc-99,1.0,cm^3/g,  
U-235,63.0,cm^3/g,  
#Np-237,55.0,cm^3/g,  
#Sr-90,200.0,cm^3/g,  
#Zn-65,2400.0,cm^3/g,  
#Eu-155,340,cm^3/g,  
#  
#Drain Rock,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
#I-129,0.0,cm^3/g,  
#Tc-99,0.2,cm^3/g,  
#U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,  
#Sr-90,24.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
#Eu-155,340,cm^3/g,  
#  
Operation Gravelly Sand,5.0,m,0,m,  
H-3,0.0,cm^3/g,  
I-129,0.0,cm^3/g,  
Tc-99,0.2,cm^3/g,  
U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,  
#Sr-90,24.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
#Eu-155,340,cm^3/g,  
#  
Waste Gravelly Sand,5.0,m,0,m,  
H-3,0.0,cm^3/g,  
I-129,0.0,cm^3/g,  
Tc-99,0.2,cm^3/g,  
U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,  
#Sr-90,12.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
#Eu-155,340,cm^3/g,  
#  
~Initial Conditions Card  
Gas Pressure,Aqueous Pressure,
```

9,  
Aqueous Pressure,,,,,,,1,60,1,1,1,98,  
Solute Volume Overwrite,H-3,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,I-129,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,Tc-99,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,U-235,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
#Solute Volume Overwrite,Np-237,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
#Solute Volume Overwrite,Sr-90,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
#Solute Volume Overwrite,Zn-65,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
#Solute Volume Overwrite,Eu-155,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
#  
Solute Volume Overwrite,H-3,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,I-129,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,Tc-99,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,U-235,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
#Solute Volume Overwrite,Np-237,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
#Solute Volume Overwrite,Sr-90,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
#Solute Volume Overwrite,Zn-65,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
#Solute Volume Overwrite,Eu-155,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
  
~Boundary Conditions Card  
3,  
#  
top,neumann,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#0.0001 m/yr \* 1.74 ICDF Recharge Ratio = 0.000174 m/yr  
1,15,1,1,98,98,1,  
0,day,-0.000174,m/yr,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#  
east,seepage face,outflow,outflow,outflow,outflow,  
#Emplace seepage face to account for leachate drain removal  
#Base of seepage face cell (Height = 0.3 m) set to atmospheric pressure  
#P = 101325 - 0.15 m \* 9793.52 = 99855.97  
15,15,1,1,85,85,1,  
0,day,99855.97,Pa,,,.,".  
#  
west,seepage face,outflow,outflow,outflow,outflow,  
#Emplace seepage face to account for leachate drain removal  
#Base of seepage face cell (Height = 0.3 m) set to atmospheric pressure  
#P = 101325 - 0.15 m \* 9793.52 = 99855.97  
1,1,1,1,85,85,1,  
0,day,99855.97,Pa,,,.,".  
#  
~Surface Flux Card  
15,  
Aqueous Volumetric Flux,m^3/yr,m^3,top,1,15,1,1,85,85,  
Solute Flux,H-3,1/yr,,top,1,15,1,1,85,85,  
Solute Flux,I-129,1/yr,,top,1,15,1,1,85,85,  
Solute Flux,Tc-99,1/yr,,top,1,15,1,1,85,85,  
Solute Flux,U-235,1/yr,,top,1,15,1,1,85,85,  
#Solute Flux,Np-237,1/yr,,top,1,15,1,1,85,85,  
#Solute Flux,Sr-90,1/yr,,top,1,15,1,1,85,85,  
#Solute Flux,Zn-65,1/yr,,top,1,15,1,1,85,85,  
#Solute Flux,Eu-155,1/yr,,top,1,15,1,1,85,85,

```
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,1,1,1,1,85,85,  
Solute Flux,H-3,1/yr,,west,1,1,1,1,85,85,  
Solute Flux,I-129,1/yr,,west,1,1,1,1,85,85,  
Solute Flux,Tc-99,1/yr,,west,1,1,1,1,85,85,  
Solute Flux,U-235,1/yr,,west,1,1,1,1,85,85,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,east,15,15,1,1,85,85,  
Solute Flux,H-3,1/yr,,east,15,15,1,1,85,85,  
Solute Flux,I-129,1/yr,,east,15,15,1,1,85,85,  
Solute Flux,Tc-99,1/yr,,east,15,15,1,1,85,85,  
Solute Flux,U-235,1/yr,,east,15,15,1,1,85,85,  
#  
~Output Control Card  
12,  
1,1,85,  
5,1,85,  
10,1,85,  
15,1,85,  
1,1,88,  
5,1,88,  
10,1,88,  
15,1,88,  
1,1,98,  
5,1,98,  
10,1,98,  
15,1,98,  
1,1,yr,m,8,8,8,  
8,  
aqueous saturation,,  
aqueous pressure,Pa,  
aqueous moisture content,,  
znc aqueous vol,m/yr,  
solute aqueous concentration,H-3,,  
solute aqueous concentration,I-129,,  
solute aqueous concentration,Tc-99,,  
solute aqueous concentration,U-235,,  
30,  
1,yr,  
2,yr,  
3,yr,  
4,yr,  
5,yr,  
6,yr,  
7,yr,  
8,yr,  
9,yr,  
10,yr,  
11,yr,  
12,yr,  
13,yr,  
14,yr,  
15,yr,  
16,yr,  
17,yr,  
18,yr,  
19,yr,
```

20, yr,  
21, yr,  
22, yr,  
23, yr,  
24, yr,  
25, yr,  
26, yr,  
27, yr,  
28, yr,  
29, yr,  
30, yr,  
8,  
aqueous saturation,,  
aqueous pressure, Pa,  
aqueous moisture content,,  
znc aqueous vol, m/yr,  
solute aqueous concentration, H-3,,  
solute aqueous concentration, I-129,,  
solute aqueous concentration, Tc-99,,  
solute aqueous concentration, U-235,,  
rock/soil type,,

## E.7. Design Recharge, Surrogates 5 – 8 Input, Part A

~Simulation Title Card

1,  
B Pond Lengthwise Cross Section,  
WJ McMahon,  
CH2M Hill Hanford,  
July 23 2001,  
10:00 AM PDT,  
3,  
This input file is the contaminant transport run for the INEEL ICDF simulation  
This construction uses the geology developed by Pete Martian  
The input parameters are based on PM reports

~Solution Control Card

Restart,restart,  
Water w/ Solute Transport,  
9,  
0,day,20,yr,0.0007,yr,0.02,yr,1.25,8,1.e-6,  
20,yr,50,yr,0.02,yr,0.05,yr,1.25,8,1.e-6,  
50,yr,100,yr,0.05,yr,0.10,yr,1.25,8,1.e-6,  
100,yr,500,yr,0.10,yr,0.50,yr,1.25,8,1.e-6,  
500,yr,1000,yr,0.50,yr,2,yr,1.25,8,1.e-6,  
1000,yr,5000,yr,2,yr,10,yr,1.25,8,1.e-6,  
5000,yr,10000,yr,10,yr,100,yr,1.25,8,1.e-6,  
10000,yr,100000,yr,100,yr,1000,yr,1.25,8,1.e-6,  
100000,yr,1000000,yr,1000,yr,10000,yr,1.25,8,1.e-6,  
8000,  
0,

~Grid Card

cartesian,  
60,1,98,  
# X Dimensions::160 m ICDF cell Total X Dimension 320 m  
0.,m,6@15,m,5@10,m,2@5,m,2@5,m,  
#20 m to screening model compliance point,  
2@5,m,1@4.,m,1@3.,m,1@2.,m,1@1.,m,  
#190 feet (or 58 m) to edge of landfill cap (less 20 m above)  
2@2.,m,1@3,m,1@4.,m,2@6.,m,1@4.,m,2@3.,m,2@2,m,1@1.,m,  
#190 feet (or 58 m) plus 20 m (less 58 m above)  
2@2.,m,1@3,m,1@4.,m,2@3.,m,1@2,m,1@1.,m,  
#190 feet (or 58 m) plus 100 m (less 78 m above)  
2@2.,m,1@3,m,2@4.,m,2@5.,m,5@8.,m,1@5.,m,1@4.,m,1@3.,m,1@2,m,1@1.,m,  
#One grid block to move last observation point off of boundary  
2@1.,m,  
# Y Dimensions (Y dimension not used)  
0.,m,1.,m,  
# Z Dimensions  
#Basalt Aquifer (Total = 76 m, Begin and End Lower 61 m) 9 Rows (Ignore 0)  
0.,m,2@12.,m,2@8.,m,2@6.,m,1@4.,m,1@3.,m,1@2.,m,  
#Basalt Aquifer Begin First 9 m of Upper 15 m 6 Rows  
6@1.5,m,  
#Basalt Aquifer Begin and End Upper 6 m  
# (7 m or 22 ft-note 6 m saturated and 1 m above water table) 6 Rows  
1@1,m,1@1,m,1@1,m,1@1,m,1@2,m,

```
#Basalt (16.98 m or 57 ft-note that 1 m added to aquifer layer, 17.98 m = 59
ft)
# 7 Rows
1@2,m,1@2.32,m,1@2.75,m,1@3.25,m,1@3,m,1@2.15,m,1@1.51,m,
#Sedimentary Interbed (7.01 m or 23 ft) 4 Rows
1@1.51,m,1@2,m,1@2,m,1@1.5,m,
#Basalt (39.93 m or 131 ft) 13 Rows
1@1.5,m,1@2,m,1@3,m,1@4,m,1@4,m,1@4.5,m,1@4.5,m,1@4,m,1@3,m,1@2.4,m,
1@1.81,m,1@1.22,m,
#Sedimentary Interbed (4.88 m or 16 ft) 4 Rows
1@1.22,m,1@1.22,m,1@1.22,m,1@1.22,m,
#Basalt (23.47 m or 77 ft) 9 Rows
1@1.22,m,1@2,m,1@3,m,1@3.5,m,1@3.75,m,1@3.5,m,1@3,m,1@2,m,1@1.5,m,
#Sedimentary Interbed (11.89 m or 39 ft) 6 Rows
1@1.5,m,1@1.94,m,1@2.45,m,1@2.45,m,1@2.15,m,1@1.4,m,
#Basalt (26.52 m or 87 ft) 13 Rows
1@1.4,m,1@2,m,1@2,m,1@3,m,1@5,m,1@5,m,1@3,m,1@1.57,m,1@1.2,m,1@1,m,1@0.6,m,
1@0.45,m,1@0.3,m,
#Alluvium changed from 9 to 5 feet (1.52 m or 5 ft) 4 Rows
1@0.30,m,1@0.46,m,1@0.46,m,1@0.30,m,
#Clay Liner (0.91 m or 3 ft) 3 Rows
1@0.30,m,1@0.31,m,1@0.30,m,
#Operations Layer (0.91 m or 3 ft) 3 Rows
1@0.30,m,1@0.31,m,1@0.30,m,
#Waste (10.40 m or 34 ft adjusted to 12.56 m to account for cube vs
trapezoid)
# 11 Rows
1@0.5,m,1@0.5,m,1@1,m,1@1,m,1@1.64,m,1@1.64,m,1@1.64,m,1@1.64,m,1@1,m,1@1,m,1
@1,m,
```

~Rock/Soil Zonation Card

```
14,
#Lower 61 m of Basalt Aquifer
Basalt Aquifer,1,60,1,1,1,9,
#Begin First 9 m of Upper 15 m of Basalt Aquifer
Basalt Aquifer,1,60,1,1,10,15,
#Upper 6 m of Basalt Aquifer
Basalt Aquifer,1,60,1,1,16,21,
#Lowest Vadose Basalt Layer
Basalt,1,60,1,1,22,28,
Interbed,1,60,1,1,29,32,
Basalt,1,60,1,1,33,45,
Interbed,1,60,1,1,46,49,
Basalt,1,60,1,1,50,58,
Interbed,1,60,1,1,59,64,
Basalt,1,60,1,1,65,77,
Alluvium,1,60,1,1,78,81,
Clay,1,60,1,1,82,84,
Operation Gravelly Sand,1,60,1,1,85,87,
Waste Gravelly Sand,1,60,1,1,88,98,
```

~Inactive Nodes Card

```
#Integer,
1,
16,60,1,1,22,98,
```

~Mechanical Properties Card

```
#Particle density = 2650 kg/m^3 except for clay and old alluvium
#Subgrade, attenuation barrier, and drain rock used in earlier models but
#not used here
#Basalt and interbed properties from P. Martian Screening Model
Basalt Aquifer,,,0.06,0.06,,,Millington and Quirk,
Interbed,,,0.487,0.487,,,Millington and Quirk,
Basalt,,,0.05,0.05,,,Millington and Quirk,
#
#Old Alluvium characteristics from Geotech report measurements
# sat. moisture content (0.422, 0.426); dry bulk density (1.60, 1.64 g/cm^3)
# particle density = 1.62 g/cm^3/(1-0.424) = 2.8125 g/cm^3
Alluvium,2812.5,kg/m^3,0.424,0.424,,,Millington and Quirk,
#Attenuation Barrier,,,0.400,0.400,,,Millington and Quirk,
#Clay characteristics per discussion with J. Dehner
Clay,2600,kg/m^3,0.390,0.390,,,Millington and Quirk,
#Drain Rock,,,0.400,0.400,,,Millington and Quirk,
Operation Gravelly Sand,,,0.275,0.275,,,Millington and Quirk,
#Operation Gravelly Sand dry bulk density = 120 lb/ft^3 (per J. Dehner)
#120 lb/ft^3*0.4536 kg/lb*1 ft^3/(0.3048 m/ft)^3 = 1922.25 kg/m^3
#Porosity Operation Gravelly Sand = 1-(1922.25/2650)= 0.275
Waste Gravelly Sand,,,0.266,0.266,,,Millington and Quirk,
#Waste Gravelly Sand dry bulk density = 121.5 lb/ft^3 (per J. Dehner)
#121.5 lb/ft^3*0.4536 kg/lb*1 ft^3/(0.3048 m)^3 = 1946.28 kg/m^3
#Porosity Waste Gravelly Sand = 1-(1946.28/2650)= 0.266
```

```
~Hydraulic Properties Card
#Properties from P. Martian Screening Model except old alluvium
Basalt Aquifer,9.00e+01,darcy,,,3.00e-01,darcy,
Interbed,6.7e-5,hc:cm/s,,,6.7e-5,hc:cm/s,
Basalt,9.00e+01,darcy,,,3.00e-01,darcy,
#Old Alluvium characteristics from Geotech report measurements
# sat. hydraulic conductivity (1.2e-07 cm/s, 6.2e-08 cm/s, 7.1e-08 cm/s)
Alluvium,1.2e-07,hc:cm/s,,,1.2e-07,hc:cm/s,
#Subgrade,1e-04,hc:cm/s,,,1e-04,hc:cm/s,
#Attenuation Barrier,1e-07,hc:cm/s,,,1e-07,hc:cm/s,
Clay,1e-07,hc:cm/s,,,1e-07,hc:cm/s,
#Drain Rock,3.0e-01,hc:cm/s,,,3.0e-01,hc:cm/s,
Operation Gravelly Sand,1e-04,hc:cm/s,,,1e-04,hc:cm/s,
Waste Gravelly Sand,1e-03,hc:cm/s,,,1e-03,hc:cm/s,
```

```
~Saturation Function Card
#Parameters from P. Martian Screening Model except old alluvium
#alpha, n, theta R, m
#m only specified for basalts, otherwise default m = 1 - 1/n
Basalt Aquifer,Nonhysteretic van Genuchten,4.0,1/m,4.5,0.0002,0.7777778,
Interbed,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.142,,,
Basalt,Nonhysteretic van Genuchten,4.0,1/m,4.5,0.0002,0.7777778,
#Old Alluvium characteristics from RETC fitting of Geotech report
measurements
Alluvium,Nonhysteretic van Genuchten,0.595,1/m,1.09,0.142,,,
#Subgrade,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.142,,,
#Attenuation Barrier,Nonhysteretic van Genuchten,0.800,1/m,1.090,0.07,,,
Clay,Nonhysteretic van Genuchten,0.800,1/m,1.109,0.07,,,
#Drain Rock,Nonhysteretic van Genuchten,493,1/m,2.190,0.005,,,
Operation Gravelly Sand,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.083,,,
Waste Gravelly Sand,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.072,,,
#
```

~Aqueous Relative Permeability Card  
#m only specified for basalts, otherwise default m = 1 - 1/n  
Basalt Aquifer,Mualem,1.9,  
Interbed,Mualem,,  
Basalt,Mualem,1.9,  
Alluvium,Mualem,,  
#Subgrade,Mualem,,  
#Attenuation Barrier,Mualem,,  
Clay,Mualem,,  
#Drain Rock,Mualem,,  
Operation Gravelly Sand,Mualem,,  
Waste Gravelly Sand,Mualem,,  
#

~Solute/Fluid Interactions Card

4,  
#H-3,conventional,1.0e-09,m^2/s,noncontinuous,,,  
#I-129,conventional,1.0e-09,m^2/s,noncontinuous,,,  
#Tc-99,conventional,1.0e-09,m^2/s,noncontinuous,,,  
#U-235,conventional,1.0e-09,m^2/s,noncontinuous,,,  
Np-237,conventional,1.0e-09,m^2/s,noncontinuous,,,  
Sr-90,conventional,1.0e-09,m^2/s,noncontinuous,,,  
Zn-65,conventional,1.0e-09,m^2/s,noncontinuous,,,  
Eu-155,conventional,1.0e-09,m^2/s,noncontinuous,,,  
0,  
#

~Solute/Porous Media Interaction Card

Basalt Aquifer,6.0,m,3.0,m,

#H-3,0.0,cm^3/g,  
#I-129,0.0,cm^3/g,  
#Tc-99,0.008,cm^3/g,  
#U-235,0.24,cm^3/g,  
Np-237,0.32,cm^3/g,  
Sr-90,0.48,cm^3/g,  
Zn-65,0.64,cm^3/g,  
Eu-155,314,cm^3/g,  
#

Interbed,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
#I-129,0.0,cm^3/g,  
#Tc-99,0.2,cm^3/g,  
#U-235,6.0,cm^3/g,  
Np-237,8.0,cm^3/g,  
Sr-90,12.0,cm^3/g,  
Zn-65,16.0,cm^3/g,  
Eu-155,340,cm^3/g,  
#

Basalt,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
#I-129,0.0,cm^3/g,  
#Tc-99,0.0,cm^3/g,  
#U-235,0.0,cm^3/g,  
Np-237,0.0,cm^3/g,  
Sr-90,0.0,cm^3/g,  
Zn-65,0.0,cm^3/g,  
Eu-155,0.0,cm^3/g,  
#

```
#Subgrade, 5.0,m,0,m,
#
Alluvium,5.0,m,0,m,
#H-3,0.0,cm^3/g,
#I-129,0.0,cm^3/g,
#Tc-99,0.2,cm^3/g,
#U-235,6.0,cm^3/g,
Np-237,8.0,cm^3/g,
Sr-90,24.0,cm^3/g,
Zn-65,16.0,cm^3/g,
Eu-155,340,cm^3/g,
#
#Attenuation Barrier,5.0,m,0,m,
#H-3,0.0,cm^3/g,
#I-129,1.0,cm^3/g,
#Tc-99,1.0,cm^3/g,
#U-235,63.0,cm^3/g,
#Np-237,55.0,cm^3/g,
#Sr-90,200.0,cm^3/g,
#Zn-65,2400.0,cm^3/g,
#Eu-155,340,cm^3/g,
#
Clay,5.0,m,0,m,
#H-3,0.0,cm^3/g,
#I-129,1.0,cm^3/g,
#Tc-99,1.0,cm^3/g,
#U-235,63.0,cm^3/g,
Np-237,55.0,cm^3/g,
Sr-90,200.0,cm^3/g,
Zn-65,2400.0,cm^3/g,
Eu-155,340,cm^3/g,
#
#Drain Rock,5.0,m,0,m,
#H-3,0.0,cm^3/g,
#I-129,0.0,cm^3/g,
#Tc-99,0.2,cm^3/g,
#U-235,6.0,cm^3/g,
#Np-237,8.0,cm^3/g,
#Sr-90,24.0,cm^3/g,
#Zn-65,16.0,cm^3/g,
#Eu-155,340,cm^3/g,
#
Operation Gravelly Sand,5.0,m,0,m,
#H-3,0.0,cm^3/g,
#I-129,0.0,cm^3/g,
#Tc-99,0.2,cm^3/g,
#U-235,6.0,cm^3/g,
Np-237,8.0,cm^3/g,
Sr-90,12.0,cm^3/g,
Zn-65,16.0,cm^3/g,
Eu-155,340,cm^3/g,
#
Waste Gravelly Sand,5.0,m,0,m,
#H-3,0.0,cm^3/g,
#I-129,0.0,cm^3/g,
#Tc-99,0.2,cm^3/g,
#U-235,6.0,cm^3/g,
```

Np-237,8.0,cm^3/g,  
Sr-90,12.0,cm^3/g,  
Zn-65,16.0,cm^3/g,  
Eu-155,340,cm^3/g,  
#  
~Initial Conditions Card  
Gas Pressure,Aqueous Pressure,  
9,  
Aqueous Pressure,,,,,,,1,60,1,1,1,83,  
#Solute Volume Overwrite,H-3,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,  
#Solute Volume Overwrite,I-129,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,  
#Solute Volume Overwrite,Tc-99,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,  
#Solute Volume Overwrite,U-235,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,Np-237,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,Sr-90,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,Zn-65,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,Eu-155,0.0,1/m^3,0,,0,,0,,1,60,1,1,1,98,  
#  
#Solute Volume Overwrite,H-3,2.0e+03,1/m^3,0,,0,,0,,1,15,1,1,88,98,  
#Solute Volume Overwrite,I-129,2.0e+03,1/m^3,0,,0,,0,,1,15,1,1,88,98,  
#Solute Volume Overwrite,Tc-99,2.0e+03,1/m^3,0,,0,,0,,1,15,1,1,88,98,  
#Solute Volume Overwrite,U-235,2.0e+03,1/m^3,0,,0,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,Np-237,1946.28,1/m^3,0,,0,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,Sr-90,1946.28,1/m^3,0,,0,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,Zn-65,1946.28,1/m^3,0,,0,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,Eu-155,1946.28,1/m^3,0,,0,,0,,1,15,1,1,88,98,  
  
~Boundary Conditions Card  
4,  
#  
top,neumann,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#0.0001 m/yr \* 1.74 ICDF Recharge Ratio = 0.000174 m/yr  
1,15,1,1,98,98,1,  
0,day,-0.000174,m/yr,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#  
west,neumann,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
1,1,1,1,20,1,  
0,day,0.06,m/day,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#  
west,neumann,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
1,1,1,1,21,21,1,  
0,day,0.03,m/day,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#  
east,hydraulic gradient,outflow,outflow,outflow,outflow,  
#Hold head constant to keep h ~ 5 m at compliance point

```
60,60,1,1,1,21,1,  
0,day,786871.34,Pa,,.,.,.,.,.,.,.,.  
#  
~Surface Flux Card  
50,  
Aqueous Volumetric Flux,m^3/yr,m^3,bottom,1,15,1,1,82,82,  
#Solute Flux,H-3,1/yr,,bottom,1,15,1,1,82,82,  
#Solute Flux,I-129,1/yr,,bottom,1,15,1,1,82,82,  
#Solute Flux,Tc-99,1/yr,,bottom,1,15,1,1,82,82,  
#Solute Flux,U-235,1/yr,,bottom,1,15,1,1,82,82,  
Solute Flux,Np-237,1/yr,,bottom,1,15,1,1,82,82,  
Solute Flux,Sr-90,1/yr,,bottom,1,15,1,1,82,82,  
Solute Flux,Zn-65,1/yr,,bottom,1,15,1,1,82,82,  
Solute Flux,Eu-155,1/yr,,bottom,1,15,1,1,82,82,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,bottom,1,15,1,1,22,22,  
#Solute Flux,H-3,1/yr,,bottom,1,15,1,1,22,22,  
#Solute Flux,I-129,1/yr,,bottom,1,15,1,1,22,22,  
#Solute Flux,Tc-99,1/yr,,bottom,1,15,1,1,22,22,  
#Solute Flux,U-235,1/yr,,bottom,1,15,1,1,22,22,  
Solute Flux,Np-237,1/yr,,bottom,1,15,1,1,22,22,  
Solute Flux,Sr-90,1/yr,,bottom,1,15,1,1,22,22,  
Solute Flux,Zn-65,1/yr,,bottom,1,15,1,1,22,22,  
Solute Flux,Eu-155,1/yr,,bottom,1,15,1,1,22,22,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,21,21,1,1,10,21,  
#Solute Flux,H-3,1/yr,,west,21,21,1,1,10,21,  
#Solute Flux,I-129,1/yr,,west,21,21,1,1,10,21,  
#Solute Flux,Tc-99,1/yr,,west,21,21,1,1,10,21,  
#Solute Flux,U-235,1/yr,,west,21,21,1,1,10,21,  
Solute Flux,Np-237,1/yr,,west,21,21,1,1,10,21,  
Solute Flux,Sr-90,1/yr,,west,21,21,1,1,10,21,  
Solute Flux,Zn-65,1/yr,,west,21,21,1,1,10,21,  
Solute Flux,Eu-155,1/yr,,west,21,21,1,1,10,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,21,21,1,1,17,21,  
#Solute Flux,H-3,1/yr,,west,21,21,1,1,17,21,  
#Solute Flux,I-129,1/yr,,west,21,21,1,1,17,21,  
#Solute Flux,Tc-99,1/yr,,west,21,21,1,1,17,21,  
#Solute Flux,U-235,1/yr,,west,21,21,1,1,17,21,  
Solute Flux,Np-237,1/yr,,west,21,21,1,1,17,21,  
Solute Flux,Sr-90,1/yr,,west,21,21,1,1,17,21,  
Solute Flux,Zn-65,1/yr,,west,21,21,1,1,17,21,  
Solute Flux,Eu-155,1/yr,,west,21,21,1,1,17,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,33,33,1,1,10,21,  
#Solute Flux,H-3,1/yr,,west,33,33,1,1,10,21,  
#Solute Flux,I-129,1/yr,,west,33,33,1,1,10,21,  
#Solute Flux,Tc-99,1/yr,,west,33,33,1,1,10,21,  
#Solute Flux,U-235,1/yr,,west,33,33,1,1,10,21,  
Solute Flux,Np-237,1/yr,,west,33,33,1,1,10,21,  
Solute Flux,Sr-90,1/yr,,west,33,33,1,1,10,21,  
Solute Flux,Zn-65,1/yr,,west,33,33,1,1,10,21,  
Solute Flux,Eu-155,1/yr,,west,33,33,1,1,10,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,33,33,1,1,17,21,  
#Solute Flux,H-3,1/yr,,west,33,33,1,1,17,21,
```

```
#Solute Flux,I-129,1/yr,,west,33,33,1,1,17,21,  
#Solute Flux,Tc-99,1/yr,,west,33,33,1,1,17,21,  
#Solute Flux,U-235,1/yr,,west,33,33,1,1,17,21,  
Solute Flux,Np-237,1/yr,,west,33,33,1,1,17,21,  
Solute Flux,Sr-90,1/yr,,west,33,33,1,1,17,21,  
Solute Flux,Zn-65,1/yr,,west,33,33,1,1,17,21,  
Solute Flux,Eu-155,1/yr,,west,33,33,1,1,17,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,41,41,1,1,10,21,  
#Solute Flux,H-3,1/yr,,west,41,41,1,1,10,21,  
#Solute Flux,I-129,1/yr,,west,41,41,1,1,10,21,  
#Solute Flux,Tc-99,1/yr,,west,41,41,1,1,10,21,  
#Solute Flux,U-235,1/yr,,west,41,41,1,1,10,21,  
Solute Flux,Np-237,1/yr,,west,41,41,1,1,10,21,  
Solute Flux,Sr-90,1/yr,,west,41,41,1,1,10,21,  
Solute Flux,Zn-65,1/yr,,west,41,41,1,1,10,21,  
Solute Flux,Eu-155,1/yr,,west,41,41,1,1,10,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,41,41,1,1,17,21,  
#Solute Flux,H-3,1/yr,,west,41,41,1,1,17,21,  
#Solute Flux,I-129,1/yr,,west,41,41,1,1,17,21,  
#Solute Flux,Tc-99,1/yr,,west,41,41,1,1,17,21,  
#Solute Flux,U-235,1/yr,,west,41,41,1,1,17,21,  
Solute Flux,Np-237,1/yr,,west,41,41,1,1,17,21,  
Solute Flux,Sr-90,1/yr,,west,41,41,1,1,17,21,  
Solute Flux,Zn-65,1/yr,,west,41,41,1,1,17,21,  
Solute Flux,Eu-155,1/yr,,west,41,41,1,1,17,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,58,58,1,1,10,21,  
#Solute Flux,H-3,1/yr,,west,58,58,1,1,10,21,  
#Solute Flux,I-129,1/yr,,west,58,58,1,1,10,21,  
#Solute Flux,Tc-99,1/yr,,west,58,58,1,1,10,21,  
#Solute Flux,U-235,1/yr,,west,58,58,1,1,10,21,  
Solute Flux,Np-237,1/yr,,west,58,58,1,1,10,21,  
Solute Flux,Sr-90,1/yr,,west,58,58,1,1,10,21,  
Solute Flux,Zn-65,1/yr,,west,58,58,1,1,10,21,  
Solute Flux,Eu-155,1/yr,,west,58,58,1,1,10,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,58,58,1,1,17,21,  
#Solute Flux,H-3,1/yr,,west,58,58,1,1,17,21,  
#Solute Flux,I-129,1/yr,,west,58,58,1,1,17,21,  
#Solute Flux,Tc-99,1/yr,,west,58,58,1,1,17,21,  
#Solute Flux,U-235,1/yr,,west,58,58,1,1,17,21,  
Solute Flux,Np-237,1/yr,,west,58,58,1,1,17,21,  
Solute Flux,Sr-90,1/yr,,west,58,58,1,1,17,21,  
Solute Flux,Zn-65,1/yr,,west,58,58,1,1,17,21,  
Solute Flux,Eu-155,1/yr,,west,58,58,1,1,17,21,  
#  
~Output Control Card  
48,  
21,1,10,  
21,1,11,  
21,1,12,  
21,1,13,  
21,1,14,  
21,1,15,
```

21,1,16,  
21,1,17,  
21,1,18,  
21,1,19,  
21,1,20,  
21,1,21,  
33,1,10,  
33,1,11,  
33,1,12,  
33,1,13,  
33,1,14,  
33,1,15,  
33,1,16,  
33,1,17,  
33,1,18,  
33,1,19,  
33,1,20,  
33,1,21,  
41,1,10,  
41,1,11,  
41,1,12,  
41,1,13,  
41,1,14,  
41,1,15,  
41,1,16,  
41,1,17,  
41,1,18,  
41,1,19,  
41,1,20,  
41,1,21,  
58,1,10,  
58,1,11,  
58,1,12,  
58,1,13,  
58,1,14,  
58,1,15,  
58,1,16,  
58,1,17,  
58,1,18,  
58,1,19,  
58,1,20,  
58,1,21,  
1,1,yr,m,8,8,8,  
8,  
aqueous saturation,,  
aqueous pressure,Pa,  
aqueous moisture content,,  
znc aqueous vol,m/yr,  
solute aqueous concentration,Np-237,,  
solute aqueous concentration,Sr-90,,  
solute aqueous concentration,Zn-65,,  
solute aqueous concentration,Eu-155,,  
12,  
#1,yr,  
10,yr,  
100,yr,  
200,yr,

500, yr,  
1000, yr,  
1200, yr,  
1500, yr,  
2000, yr,  
#2500, yr,  
5000, yr,  
10000, yr,  
#20000, yr,  
50000, yr,  
100000, yr,  
#200000, yr,  
8,  
aqueous saturation,,  
aqueous pressure, Pa,  
aqueous moisture content,,  
znc aqueous vol, m/yr,  
solute aqueous concentration, Np-237,,  
solute aqueous concentration, Sr-90,,  
solute aqueous concentration, Zn-65,,  
solute aqueous concentration, Eu-155,,  
rock/soil type,,

## E.8. Design Recharge, Surrogates 5 – 8 Input, Part B

~Simulation Title Card

1,  
INEEL Lengthwise Cross Section,  
WJ McMahon,  
CH2M Hill Hanford,  
November 29 2001,  
5:00 PM PDT,  
3,  
This input file is the contaminant transport run for the INEEL ICDF simulation  
This construction uses the geology developed by Pete Martian  
The input parameters are based on PM reports

~Solution Control Card

Restart,restart,  
Water w/ Solute Transport,  
2,  
0,day,20,yr,0.0007,yr,0.02,yr,1.25,8,1.e-6,  
20,yr,30,yr,0.02,yr,0.05,yr,1.25,8,1.e-6,  
8000,  
0,

~Grid Card

cartesian,  
60,1,98,  
# X Dimensions::160 m ICDF cell Total X Dimension 320 m  
0.,m,6@15,m,5@10,m,2@5,m,2@5,m,  
#20 m to screening model compliance point,  
2@5,m,1@4.,m,1@3.,m,1@2.,m,1@1.,m,  
#190 feet (or 58 m) to edge of landfill cap (less 20 m above)  
2@2.,m,1@3,m,1@4.,m,2@6.,m,1@4.,m,2@3.,m,2@2,m,1@1.,m,  
#190 feet (or 58 m) plus 20 m (less 58 m above)  
2@2.,m,1@3,m,1@4.,m,2@3.,m,1@2,m,1@1.,m,  
#190 feet (or 58 m) plus 100 m (less 78 m above)  
2@2.,m,1@3,m,2@4.,m,2@5.,m,5@8.,m,1@5.,m,1@4.,m,1@3.,m,1@2,m,1@1.,m,  
#One grid block to move last observation point off of boundary  
2@1.,m,  
# Y Dimensions (Y dimension not used)  
0.,m,1.,m,  
# Z Dimensions  
#Basalt Aquifer (Total = 76 m, Begin and End Lower 61 m) 9 Rows (Ignore 0)  
0.,m,2@12.,m,2@8.,m,2@6.,m,1@4.,m,1@3.,m,1@2.,m,  
#Basalt Aquifer Begin First 9 m of Upper 15 m 6 Rows  
6@1.5,m,  
#Basalt Aquifer Begin and End Upper 6 m  
# (7 m or 22 ft-note 6 m saturated and 1 m above water table) 6 Rows  
1@1,m,1@1,m,1@1,m,1@1,m,1@2,m,  
#Basalt (16.98 m or 57 ft-note that 1 m added to aquifer layer, 17.98 m = 59 ft)  
# 7 Rows  
1@2,m,1@2.32,m,1@2.75,m,1@3.25,m,1@3,m,1@2.15,m,1@1.51,m,  
#Sedimentary Interbed (7.01 m or 23 ft) 4 Rows  
1@1.51,m,1@2,m,1@2,m,1@1.5,m,  
#Basalt (39.93 m or 131 ft) 13 Rows

1@1.5,m,1@2,m,1@3,m,1@4,m,1@4,m,1@4.5,m,1@4.5,m,1@4,m,1@4,m,1@3,m,1@2.4,m,  
1@1.81,m,1@1.22,m,  
#Sedimentary Interbed (4.88 m or 16 ft) 4 Rows  
1@1.22,m,1@1.22,m,1@1.22,m,1@1.22,m,  
#Basalt (23.47 m or 77 ft) 9 Rows  
1@1.22,m,1@2,m,1@3,m,1@3.5,m,1@3.75,m,1@3.5,m,1@3,m,1@2,m,1@1.5,m,  
#Sedimentary Interbed (11.89 m or 39 ft) 6 Rows  
1@1.5,m,1@1.94,m,1@2.45,m,1@2.45,m,1@2.15,m,1@1.4,m,  
#Basalt (26.52 m or 87 ft) 13 Rows  
1@1.4,m,1@2,m,1@2,m,1@3,m,1@5,m,1@3,m,1@1.57,m,1@1.2,m,1@1,m,1@0.6,m,  
1@0.45,m,1@0.3,m,  
#Alluvium changed from 9 to 5 feet (1.52 m or 5 ft) 4 Rows  
1@0.30,m,1@0.46,m,1@0.46,m,1@0.30,m,  
#Clay Liner (0.91 m or 3 ft) 3 Rows  
1@0.30,m,1@0.31,m,1@0.30,m,  
#Operations Layer (0.91 m or 3 ft) 3 Rows  
1@0.30,m,1@0.31,m,1@0.30,m,  
#Waste (10.40 m or 34 ft adjusted to 12.56 m to account for cube vs  
trapezoid)  
# 11 Rows  
1@0.5,m,1@0.5,m,1@1,m,1@1,m,1@1.64,m,1@1.64,m,1@1.64,m,1@1,m,1@1,m,1  
@1,m,

~Rock/Soil Zonation Card

14,  
#Lower 61 m of Basalt Aquifer  
Basalt Aquifer,1,60,1,1,1,9,  
#Begin First 9 m of Upper 15 m of Basalt Aquifer  
Basalt Aquifer,1,60,1,1,10,15,  
#Upper 6 m of Basalt Aquifer  
Basalt Aquifer,1,60,1,1,16,21,  
#Lowest Vadose Basalt Layer  
Basalt,1,60,1,1,22,28,  
Interbed,1,60,1,1,29,32,  
Basalt,1,60,1,1,33,45,  
Interbed,1,60,1,1,46,49,  
Basalt,1,60,1,1,50,58,  
Interbed,1,60,1,1,59,64,  
Basalt,1,60,1,1,65,77,  
Alluvium,1,60,1,1,78,81,  
Clay,1,60,1,1,82,84,  
Operation Gravelly Sand,1,60,1,1,85,87,  
Waste Gravelly Sand,1,60,1,1,88,98,

#  
~Inactive Nodes Card

#Integer,  
2,  
16,60,1,1,1,98,  
1,15,1,1,1,84,  
#

~Mechanical Properties Card

#Particle density = 2650 kg/m^3 except for clay and old alluvium  
#Subgrade, attenuation barrier, and drain rock used in earlier models but  
#not used here  
#Basalt and interbed properties from P. Martian Screening Model  
Basalt Aquifer,,,0.06,0.06,,,Millington and Quirk,  
Interbed,,,0.487,0.487,,,Millington and Quirk,

```
Basalt,,,0.05,0.05,,,Millington and Quirk,  
#  
#Old Alluvium characteristics from Geotech report measurements  
# sat. moisture content (0.422, 0.426); dry bulk density (1.60, 1.64 g/cm^3)  
# particle density = 1.62 g/cm^3/(1-0.424) = 2.8125 g/cm^3  
Alluvium,2812.5,kg/m^3,0.424,0.424,,,Millington and Quirk,  
#Attenuation Barrier,,,0.400,0.400,,,Millington and Quirk,  
#Clay characteristics per discussion with J. Dehner  
Clay,2600,kg/m^3,0.390,0.390,,,Millington and Quirk,  
#Drain Rock,,,0.400,0.400,,,Millington and Quirk,  
Operation Gravelly Sand,,,0.275,0.275,,,Millington and Quirk,  
#Operation Gravelly Sand dry bulk density = 120 lb/ft^3 (per J. Dehner)  
#120 lb/ft^3*0.4536 kg/lb*1 ft^3/(0.3048 m/ft)^3 = 1922.25 kg/m^3  
#Porosity Operation Gravelly Sand = 1-(1922.25/2650)= 0.275  
Waste Gravelly Sand,,,0.266,0.266,,,Millington and Quirk,  
#Waste Gravelly Sand dry bulk density = 121.5 lb/ft^3 (per J. Dehner)  
#121.5 lb/ft^3*0.4536 kg/lb*1 ft^3/(0.3048 m)^3 = 1946.28 kg/m^3  
#Porosity Waste Gravelly Sand = 1-(1946.28/2650)= 0.266
```

~Hydraulic Properties Card

```
#Properties from P. Martian Screening Model except old alluvium  
Basalt Aquifer,9.00e+01,darcy,,,3.00e-01,darcy,  
Interbed,6.7e-5,hc:cm/s,,,6.7e-5,hc:cm/s,  
Basalt,9.00e+01,darcy,,,3.00e-01,darcy,  
#Old Alluvium characteristics from Geotech report measurements  
# sat. hydraulic conductivity (1.2e-07 cm/s, 6.2e-08 cm/s, 7.1e-08 cm/s)  
Alluvium,1.2e-07,hc:cm/s,,,1.2e-07,hc:cm/s,  
#Subgrade,1e-04,hc:cm/s,,,1e-04,hc:cm/s,  
#Attenuation Barrier,1e-07,hc:cm/s,,,1e-07,hc:cm/s,  
Clay,1e-07,hc:cm/s,,,1e-07,hc:cm/s,  
#Drain Rock,3.0e-01,hc:cm/s,,,3.0e-01,hc:cm/s,  
Operation Gravelly Sand,1e-04,hc:cm/s,,,1e-04,hc:cm/s,  
Waste Gravelly Sand,1e-03,hc:cm/s,,,1e-03,hc:cm/s,
```

~Saturation Function Card

```
#Parameters from P. Martian Screening Model except old alluvium  
#alpha, n, theta R, m  
#m only specified for basalts, otherwise default m = 1 - 1/n  
Basalt Aquifer,Nonhysteretic van Genuchten,4.0,1/m,4.5,0.0002,0.7777778,  
Interbed,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.142,,  
Basalt,Nonhysteretic van Genuchten,4.0,1/m,4.5,0.0002,0.7777778,  
#Old Alluvium characteristics from RETC fitting of Geotech report  
measurements  
Alluvium,Nonhysteretic van Genuchten,0.595,1/m,1.09,0.142,,  
#Subgrade,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.142,,  
#Attenuation Barrier,Nonhysteretic van Genuchten,0.800,1/m,1.090,0.07,,  
Clay,Nonhysteretic van Genuchten,0.800,1/m,1.109,0.07,,  
#Drain Rock,Nonhysteretic van Genuchten,493,1/m,2.190,0.005,,  
Operation Gravelly Sand,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.083,,  
Waste Gravelly Sand,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.072,,  
#
```

~Aqueous Relative Permeability Card

```
#m only specified for basalts, otherwise default m = 1 - 1/n  
Basalt Aquifer,Mualem,1.9,  
Interbed,Mualem,,  
Basalt,Mualem,1.9,  
Alluvium,Mualem,,
```

```
#Subgrade,Mualem,,  
#Attenuation Barrier,Mualem,,  
Clay,Mualem,,  
#Drain Rock,Mualem,,  
Operation Gravelly Sand,Mualem,,  
Waste Gravelly Sand,Mualem,,  
#  
  
~Solute/Fluid Interactions Card  
4,  
#H-3,conventional,1.0e-09,m^2/s,noncontinuous,,,  
#I-129,conventional,1.0e-09,m^2/s,noncontinuous,,,  
#Tc-99,conventional,1.0e-09,m^2/s,noncontinuous,,,  
#U-235,conventional,1.0e-09,m^2/s,noncontinuous,,,  
Np-237,conventional,1.0e-09,m^2/s,noncontinuous,,,  
Sr-90,conventional,1.0e-09,m^2/s,noncontinuous,,,  
Zn-65,conventional,1.0e-09,m^2/s,noncontinuous,,,  
Eu-155,conventional,1.0e-09,m^2/s,noncontinuous,,,  
0,  
#  
~Solute/Porous Media Interaction Card  
Basalt Aquifer,6.0,m,3.0,m,  
#H-3,0.0,cm^3/g,  
#I-129,0.0,cm^3/g,  
#Tc-99,0.008,cm^3/g,  
#U-235,0.24,cm^3/g,  
Np-237,0.32,cm^3/g,  
Sr-90,0.48,cm^3/g,  
Zn-65,0.64,cm^3/g,  
Eu-155,314,cm^3/g,  
#  
Interbed,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
#I-129,0.0,cm^3/g,  
#Tc-99,0.2,cm^3/g,  
#U-235,6.0,cm^3/g,  
Np-237,8.0,cm^3/g,  
Sr-90,12.0,cm^3/g,  
Zn-65,16.0,cm^3/g,  
Eu-155,340,cm^3/g,  
#  
Basalt,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
#I-129,0.0,cm^3/g,  
#Tc-99,0.0,cm^3/g,  
#U-235,0.0,cm^3/g,  
Np-237,0.0,cm^3/g,  
Sr-90,0.0,cm^3/g,  
Zn-65,0.0,cm^3/g,  
Eu-155,0.0,cm^3/g,  
#  
#Subgrade,5.0,m,0,m,  
#  
Alluvium,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
#I-129,0.0,cm^3/g,  
#Tc-99,0.2,cm^3/g,
```

```
#U-235,6.0,cm^3/g,  
Np-237,8.0,cm^3/g,  
Sr-90,24.0,cm^3/g,  
Zn-65,16.0,cm^3/g,  
Eu-155,340,cm^3/g,  
#  
#Attenuation Barrier,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
#I-129,1.0,cm^3/g,  
#Tc-99,1.0,cm^3/g,  
#U-235,63.0,cm^3/g,  
#Np-237,55.0,cm^3/g,  
#Sr-90,200.0,cm^3/g,  
#Zn-65,2400.0,cm^3/g,  
#Eu-155,340,cm^3/g,  
#  
Clay,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
#I-129,1.0,cm^3/g,  
#Tc-99,1.0,cm^3/g,  
#U-235,63.0,cm^3/g,  
Np-237,55.0,cm^3/g,  
Sr-90,200.0,cm^3/g,  
Zn-65,2400.0,cm^3/g,  
Eu-155,340,cm^3/g,  
#  
#Drain Rock,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
#I-129,0.0,cm^3/g,  
#Tc-99,0.2,cm^3/g,  
#U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,  
#Sr-90,24.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
#Eu-155,340,cm^3/g,  
#  
Operation Gravelly Sand,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
#I-129,0.0,cm^3/g,  
#Tc-99,0.2,cm^3/g,  
#U-235,6.0,cm^3/g,  
Np-237,8.0,cm^3/g,  
Sr-90,12.0,cm^3/g,  
Zn-65,16.0,cm^3/g,  
Eu-155,340,cm^3/g,  
#  
Waste Gravelly Sand,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
#I-129,0.0,cm^3/g,  
#Tc-99,0.2,cm^3/g,  
#U-235,6.0,cm^3/g,  
Np-237,8.0,cm^3/g,  
Sr-90,12.0,cm^3/g,  
Zn-65,16.0,cm^3/g,  
Eu-155,340,cm^3/g,  
#  
~Initial Conditions Card
```

Gas Pressure, Aqueous Pressure,  
9,  
Aqueous Pressure,,,,,,1,60,1,1,1,98,  
#Solute Volume Overwrite,H-3,0.0,1/m^3,0,,,0,,1,60,1,1,1,98,  
#Solute Volume Overwrite,I-129,0.0,1/m^3,0,,,0,,1,60,1,1,1,98,  
#Solute Volume Overwrite,Tc-99,0.0,1/m^3,0,,,0,,1,60,1,1,1,98,  
#Solute Volume Overwrite,U-235,0.0,1/m^3,0,,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,Np-237,0.0,1/m^3,0,,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,Sr-90,0.0,1/m^3,0,,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,Zn-65,0.0,1/m^3,0,,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,Eu-155,0.0,1/m^3,0,,,0,,1,60,1,1,1,98,  
#  
#Solute Volume Overwrite,H-3,2.0e+03,1/m^3,0,,,0,,1,15,1,1,88,98,  
#Solute Volume Overwrite,I-129,2.0e+03,1/m^3,0,,,0,,1,15,1,1,88,98,  
#Solute Volume Overwrite,Tc-99,2.0e+03,1/m^3,0,,,0,,1,15,1,1,88,98,  
#Solute Volume Overwrite,U-235,2.0e+03,1/m^3,0,,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,Np-237,1946.28,1/m^3,0,,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,Sr-90,1946.28,1/m^3,0,,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,Zn-65,1946.28,1/m^3,0,,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,Eu-155,1946.28,1/m^3,0,,,0,,1,15,1,1,88,98,

~Boundary Conditions Card  
3,  
#  
top,neumann,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#0.0001 m/yr \* 1.74 ICDF Recharge Ratio = 0.000174 m/yr  
1,15,1,1,98,98,1,  
0,day,-0.000174,m/yr,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#  
east,seepage face,outflow,outflow,outflow,outflow,  
#Emplace seepage face to account for leachate drain removal  
#Base of seepage face cell (Height = 0.3 m) set to atmospheric pressure  
#P = 101325 - 0.15 m \* 9793.52 = 99855.97  
15,15,1,1,85,85,1,  
0,day,99855.97,Pa,,,,,,,,,,  
#  
west,seepage face,outflow,outflow,outflow,outflow,  
#Emplace seepage face to account for leachate drain removal  
#Base of seepage face cell (Height = 0.3 m) set to atmospheric pressure  
#P = 101325 - 0.15 m \* 9793.52 = 99855.97  
1,1,1,1,85,85,1,  
0,day,99855.97,Pa,,,,,,,,,,  
#  
#  
~Surface Flux Card  
15,  
Aqueous Volumetric Flux,m^3/yr,m^3,top,1,15,1,1,85,85,  
#Solute Flux,H-3,1/yr,,top,1,15,1,1,85,85,  
#Solute Flux,I-129,1/yr,,top,1,15,1,1,85,85,  
#Solute Flux,Tc-99,1/yr,,top,1,15,1,1,85,85,  
#Solute Flux,U-235,1/yr,,top,1,15,1,1,85,85,  
Solute Flux,Np-237,1/yr,,top,1,15,1,1,85,85,  
Solute Flux,Sr-90,1/yr,,top,1,15,1,1,85,85,

```
Solute Flux,Zn-65,1/yr,,top,1,15,1,1,85,85,  
Solute Flux,Eu-155,1/yr,,top,1,15,1,1,85,85,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,1,1,1,1,85,85,  
Solute Flux,Np-237,1/yr,,west,1,1,1,1,85,85,  
Solute Flux,Sr-90,1/yr,,west,1,1,1,1,85,85,  
Solute Flux,Zn-65,1/yr,,west,1,1,1,1,85,85,  
Solute Flux,Eu-155,1/yr,,west,1,1,1,1,85,85,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,east,15,15,1,1,85,85,  
Solute Flux,Np-237,1/yr,,east,15,15,1,1,85,85,  
Solute Flux,Sr-90,1/yr,,east,15,15,1,1,85,85,  
Solute Flux,Zn-65,1/yr,,east,15,15,1,1,85,85,  
Solute Flux,Eu-155,1/yr,,east,15,15,1,1,85,85,  
#  
~Output Control Card  
12,  
1,1,85,  
5,1,85,  
10,1,85,  
15,1,85,  
1,1,88,  
5,1,88,  
10,1,88,  
15,1,88,  
1,1,98,  
5,1,98,  
10,1,98,  
15,1,98,  
1,1,yr,m,8,8,8,  
8,  
aqueous saturation,,  
aqueous pressure,Pa,  
aqueous moisture content,,  
znc aqueous vol,m/yr,  
solute aqueous concentration,Np-237,,  
solute aqueous concentration,Sr-90,,  
solute aqueous concentration,Zn-65,,  
solute aqueous concentration,Eu-155,,  
30,  
1,yr,  
2,yr,  
3,yr,  
4,yr,  
5,yr,  
6,yr,  
7,yr,  
8,yr,  
9,yr,  
10,yr,  
11,yr,  
12,yr,  
13,yr,  
14,yr,  
15,yr,  
16,yr,  
17,yr,
```

18, yr,  
19, yr,  
20, yr,  
21, yr,  
22, yr,  
23, yr,  
24, yr,  
25, yr,  
26, yr,  
27, yr,  
28, yr,  
29, yr,  
30, yr,  
8,  
aqueous saturation,,  
aqueous pressure, Pa,  
aqueous moisture content,,  
znc aqueous vol, m/yr,  
solute aqueous concentration, Np-237,,  
solute aqueous concentration, Sr-90,,  
solute aqueous concentration, Zn-65,,  
solute aqueous concentration, Eu-155,,  
rock/soil type,,

## E.9. Design Recharge, Surrogates 9 – 12 Input, Part A

~Simulation Title Card

1,  
B Pond Lengthwise Cross Section,  
WJ McMahon,  
CH2M Hill Hanford,  
July 23 2001,  
10:00 AM PDT,  
3,  
This input file is the contaminant transport run for the INEEL ICDF simulation  
This construction uses the geology developed by Pete Martian  
The input parameters are based on PM reports

~Solution Control Card

Restart,restart,  
Water w/ Solute Transport,  
9,  
0,day,20,yr,0.0007,yr,0.02,yr,1.25,8,1.e-6,  
20,yr,50,yr,0.02,yr,0.05,yr,1.25,8,1.e-6,  
50,yr,100,yr,0.05,yr,0.10,yr,1.25,8,1.e-6,  
100,yr,500,yr,0.10,yr,0.5,yr,1.25,8,1.e-6,  
500,yr,1000,yr,0.5,yr,2,yr,1.25,8,1.e-6,  
1000,yr,5000,yr,2,yr,10,yr,1.25,8,1.e-6,  
5000,yr,10000,yr,10,yr,100,yr,1.25,8,1.e-6,  
10000,yr,100000,yr,100,yr,1000,yr,1.25,8,1.e-6,  
100000,yr,1000000,yr,1000,yr,10000,yr,1.25,8,1.e-6,  
8000,  
0,

~Grid Card

cartesian,  
60,1,98,  
# X Dimensions::160 m ICDF cell Total X Dimension 320 m  
0.,m,6@15,m,5@10,m,2@5,m,2@5,m,  
#20 m to screening model compliance point,  
2@5,m,1@4.,m,1@3.,m,1@2.,m,1@1.,m,  
#190 feet (or 58 m) to edge of landfill cap (less 20 m above)  
2@2.,m,1@3,m,1@4.,m,2@6.,m,1@4.,m,2@3.,m,2@2,m,1@1.,m,  
#190 feet (or 58 m) plus 20 m (less 58 m above)  
2@2.,m,1@3,m,1@4.,m,2@3.,m,1@2,m,1@1.,m,  
#190 feet (or 58 m) plus 100 m (less 78 m above)  
2@2.,m,1@3,m,2@4.,m,2@5.,m,5@8.,m,1@5.,m,1@4.,m,1@3.,m,1@2,m,1@1.,m,  
#One grid block to move last observation point off of boundary  
2@1.,m,  
# Y Dimensions (Y dimension not used)  
0.,m,1.,m,  
# Z Dimensions  
#Basalt Aquifer (Total = 76 m, Begin and End Lower 61 m) 9 Rows (Ignore 0)  
0.,m,2@12.,m,2@8.,m,2@6.,m,1@4.,m,1@3.,m,1@2.,m,  
#Basalt Aquifer Begin First 9 m of Upper 15 m 6 Rows  
6@1.5,m,  
#Basalt Aquifer Begin and End Upper 6 m  
# (7 m or 22 ft-note 6 m saturated and 1 m above water table) 6 Rows  
1@1,m,1@1,m,1@1,m,1@1,m,1@1,m,1@2,m,

```
#Basalt (16.98 m or 57 ft-note that 1 m added to aquifer layer, 17.98 m = 59
ft)
# 7 Rows
1@2,m,1@2.32,m,1@2.75,m,1@3.25,m,1@3,m,1@2.15,m,1@1.51,m,
#Sedimentary Interbed (7.01 m or 23 ft) 4 Rows
1@1.51,m,1@2,m,1@2,m,1@1.5,m,
#Basalt (39.93 m or 131 ft) 13 Rows
1@1.5,m,1@2,m,1@3,m,1@4,m,1@4,m,1@4.5,m,1@4.5,m,1@4,m,1@3,m,1@2.4,m,
1@1.81,m,1@1.22,m,
#Sedimentary Interbed (4.88 m or 16 ft) 4 Rows
1@1.22,m,1@1.22,m,1@1.22,m,1@1.22,m,
#Basalt (23.47 m or 77 ft) 9 Rows
1@1.22,m,1@2,m,1@3,m,1@3.5,m,1@3.75,m,1@3.5,m,1@3,m,1@2,m,1@1.5,m,
#Sedimentary Interbed (11.89 m or 39 ft) 6 Rows
1@1.5,m,1@1.94,m,1@2.45,m,1@2.45,m,1@2.15,m,1@1.4,m,
#Basalt (26.52 m or 87 ft) 13 Rows
1@1.4,m,1@2,m,1@2,m,1@3,m,1@5,m,1@5,m,1@3,m,1@1.57,m,1@1.2,m,1@1,m,1@0.6,m,
1@0.45,m,1@0.3,m,
#Alluvium changed from 9 to 5 feet (1.52 m or 5 ft) 4 Rows
1@0.30,m,1@0.46,m,1@0.46,m,1@0.30,m,
#Clay Liner (0.91 m or 3 ft) 3 Rows
1@0.30,m,1@0.31,m,1@0.30,m,
#Operations Layer (0.91 m or 3 ft) 3 Rows
1@0.30,m,1@0.31,m,1@0.30,m,
#Waste (10.40 m or 34 ft adjusted to 12.56 m to account for cube vs
trapezoid)
# 11 Rows
1@0.5,m,1@0.5,m,1@1,m,1@1,m,1@1.64,m,1@1.64,m,1@1.64,m,1@1.64,m,1@1,m,1@1,m,1
@1,m,
```

~Rock/Soil Zonation Card

```
14,
#Lower 61 m of Basalt Aquifer
Basalt Aquifer,1,60,1,1,1,9,
#Begin First 9 m of Upper 15 m of Basalt Aquifer
Basalt Aquifer,1,60,1,1,10,15,
#Upper 6 m of Basalt Aquifer
Basalt Aquifer,1,60,1,1,16,21,
#Lowest Vadose Basalt Layer
Basalt,1,60,1,1,22,28,
Interbed,1,60,1,1,29,32,
Basalt,1,60,1,1,33,45,
Interbed,1,60,1,1,46,49,
Basalt,1,60,1,1,50,58,
Interbed,1,60,1,1,59,64,
Basalt,1,60,1,1,65,77,
Alluvium,1,60,1,1,78,81,
Clay,1,60,1,1,82,84,
Operation Gravelly Sand,1,60,1,1,85,87,
Waste Gravelly Sand,1,60,1,1,88,98,
```

~Inactive Nodes Card

```
#Integer,
1,
16,60,1,1,22,98,
```

~Mechanical Properties Card

```
#Particle density = 2650 kg/m^3 except for clay and old alluvium
#Subgrade, attenuation barrier, and drain rock used in earlier models but
#not used here
#Basalt and interbed properties from P. Martian Screening Model
Basalt Aquifer,,,0.06,0.06,,,Millington and Quirk,
Interbed,,,0.487,0.487,,,Millington and Quirk,
Basalt,,,0.05,0.05,,,Millington and Quirk,
#
#Old Alluvium characteristics from Geotech report measurements
# sat. moisture content (0.422, 0.426); dry bulk density (1.60, 1.64 g/cm^3)
# particle density = 1.62 g/cm^3/(1-0.424) = 2.8125 g/cm^3
Alluvium,2812.5,kg/m^3,0.424,0.424,,,Millington and Quirk,
#Attenuation Barrier,,,0.400,0.400,,,Millington and Quirk,
#Clay characteristics per discussion with J. Dehner
Clay,2600,kg/m^3,0.390,0.390,,,Millington and Quirk,
#Drain Rock,,,0.400,0.400,,,Millington and Quirk,
Operation Gravelly Sand,,,0.275,0.275,,,Millington and Quirk,
#Operation Gravelly Sand dry bulk density = 120 lb/ft^3 (per J. Dehner)
#120 lb/ft^3*0.4536 kg/lb*1 ft^3/(0.3048 m/ft)^3 = 1922.25 kg/m^3
#Porosity Operation Gravelly Sand = 1-(1922.25/2650)= 0.275
Waste Gravelly Sand,,,0.266,0.266,,,Millington and Quirk,
#Waste Gravelly Sand dry bulk density = 121.5 lb/ft^3 (per J. Dehner)
#121.5 lb/ft^3*0.4536 kg/lb*1 ft^3/(0.3048 m)^3 = 1946.28 kg/m^3
#Porosity Waste Gravelly Sand = 1-(1946.28/2650)= 0.266
```

```
~Hydraulic Properties Card
#Properties from P. Martian Screening Model except old alluvium
Basalt Aquifer,9.00e+01,darcy,,,3.00e-01,darcy,
Interbed,6.7e-5,hc:cm/s,,,6.7e-5,hc:cm/s,
Basalt,9.00e+01,darcy,,,3.00e-01,darcy,
#Old Alluvium characteristics from Geotech report measurements
# sat. hydraulic conductivity (1.2e-07 cm/s, 6.2e-08 cm/s, 7.1e-08 cm/s)
Alluvium,1.2e-07,hc:cm/s,,,1.2e-07,hc:cm/s,
#Subgrade,1e-04,hc:cm/s,,,1e-04,hc:cm/s,
#Attenuation Barrier,1e-07,hc:cm/s,,,1e-07,hc:cm/s,
Clay,1e-07,hc:cm/s,,,1e-07,hc:cm/s,
#Drain Rock,3.0e-01,hc:cm/s,,,3.0e-01,hc:cm/s,
Operation Gravelly Sand,1e-04,hc:cm/s,,,1e-04,hc:cm/s,
Waste Gravelly Sand,1e-03,hc:cm/s,,,1e-03,hc:cm/s,
```

```
~Saturation Function Card
#Parameters from P. Martian Screening Model except old alluvium
#alpha, n, theta R, m
#m only specified for basalts, otherwise default m = 1 - 1/n
Basalt Aquifer,Nonhysteretic van Genuchten,4.0,1/m,4.5,0.0002,0.7777778,
Interbed,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.142,,,
Basalt,Nonhysteretic van Genuchten,4.0,1/m,4.5,0.0002,0.7777778,
#Old Alluvium characteristics from RETC fitting of Geotech report
measurements
Alluvium,Nonhysteretic van Genuchten,0.595,1/m,1.09,0.142,,,
#Subgrade,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.142,,,
#Attenuation Barrier,Nonhysteretic van Genuchten,0.800,1/m,1.090,0.07,,,
Clay,Nonhysteretic van Genuchten,0.800,1/m,1.109,0.07,,,
#Drain Rock,Nonhysteretic van Genuchten,493,1/m,2.190,0.005,,,
Operation Gravelly Sand,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.083,,,
Waste Gravelly Sand,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.072,,,
#
```

```
~Aqueous Relative Permeability Card
#m only specified for basalts, otherwise default m = 1 - 1/n
Basalt Aquifer,Mualem,1.9,
Interbed,Mualem.,
Basalt,Mualem,1.9,
Alluvium,Mualem.,
#Subgrade,Mualem.,
#Attenuation Barrier,Mualem.,
Clay,Mualem.,
#Drain Rock,Mualem.,
Operation Gravelly Sand,Mualem.,
Waste Gravelly Sand,Mualem.,
#
~Solute/Fluid Interactions Card
4,
#H-3,conventional,1.0e-09,m^2/s,noncontinuous,,,,
I-129A,conventional,1.0e-09,m^2/s,noncontinuous,,,,
I-129B,conventional,1.0e-09,m^2/s,noncontinuous,,,,
#U-235,conventional,1.0e-09,m^2/s,noncontinuous,,,,
#Np-237,conventional,1.0e-09,m^2/s,noncontinuous,,,,
Sr-90,conventional,1.0e-09,m^2/s,noncontinuous,,,,
#Zn-65,conventional,1.0e-09,m^2/s,noncontinuous,,,,
Eu-155,conventional,1.0e-09,m^2/s,noncontinuous,,,,
0,
#
~Solute/Porous Media Interaction Card
Basalt Aquifer,6.0,m,3.0,m,
#H-3,0.0,cm^3/g,
I-129A,0.0,cm^3/g,
I-129B,0.0,cm^3/g,
#U-235,0.24,cm^3/g,
#Np-237,0.32,cm^3/g,
Sr-90,0.48,cm^3/g,
#Zn-65,0.64,cm^3/g,
Eu-155,13.6,cm^3/g,
#
Interbed,5.0,m,0,m,
#H-3,0.0,cm^3/g,
I-129A,0.0,cm^3/g,
I-129B,0.1,cm^3/g,
#U-235,6.0,cm^3/g,
#Np-237,8.0,cm^3/g,
Sr-90,12.0,cm^3/g,
#Zn-65,16.0,cm^3/g,
Eu-155,340,cm^3/g,
#
Basalt,5.0,m,0,m,
#H-3,0.0,cm^3/g,
I-129A,0.0,cm^3/g,
I-129B,0.0,cm^3/g,
#U-235,0.0,cm^3/g,
#Np-237,0.0,cm^3/g,
Sr-90,0.0,cm^3/g,
#Zn-65,0.0,cm^3/g,
Eu-155,0,cm^3/g,
#
#Subgrade,5.0,m,0,m,
```

```
#  
Alluvium,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
I-129A,0.0,cm^3/g,  
I-129B,0.1,cm^3/g,  
#U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,  
Sr-90,24.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
Eu-155,340,cm^3/g,  
#  
#Attenuation Barrier,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
#I-129A,1.0,cm^3/g,  
#I-129B,1.0,cm^3/g,  
#U-235,63.0,cm^3/g,  
#Np-237,55.0,cm^3/g,  
#Sr-90,200.0,cm^3/g,  
#Zn-65,2400.0,cm^3/g,  
#Eu-155,340,cm^3/g,  
#  
Clay,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
I-129A,1.0,cm^3/g,  
I-129B,1.0,cm^3/g,  
#U-235,63.0,cm^3/g,  
#Np-237,55.0,cm^3/g,  
Sr-90,200.0,cm^3/g,  
#Zn-65,2400.0,cm^3/g,  
Eu-155,340,cm^3/g,  
#  
#Drain Rock,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
#I-129A,0.0,cm^3/g,  
#I-129B,0.1,cm^3/g,  
#U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,  
#Sr-90,24.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
#Eu-155,340,cm^3/g,  
#  
Operation Gravelly Sand,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
I-129A,0.0,cm^3/g,  
I-129B,0.1,cm^3/g,  
#U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,  
Sr-90,12.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
Eu-155,340,cm^3/g,  
#  
Waste Gravelly Sand,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
I-129A,0.1,cm^3/g,  
I-129B,0.1,cm^3/g,  
#U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,
```

```
Sr-90,12.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
Eu-155,340,cm^3/g,  
#  
~Initial Conditions Card  
Gas Pressure,Aqueous Pressure,  
9,  
Aqueous Pressure,,,,,,,1,60,1,1,1,98,  
#Solute Volume Overwrite,H-3,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,I-129A,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,I-129B,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
#Solute Volume Overwrite,U-235,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
#Solute Volume Overwrite,Np-237,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,Sr-90,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
#Solute Volume Overwrite,Zn-65,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,Eu-155,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
#  
#Solute Volume Overwrite,H-3,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,I-129A,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,I-129B,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
#Solute Volume Overwrite,U-235,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
#Solute Volume Overwrite,Np-237,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,Sr-90,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
#Solute Volume Overwrite,Zn-65,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,Eu-155,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
  
~Boundary Conditions Card  
4,  
#  
top,neumann,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#0.0001 m/yr * 1.74 ICDF Recharge Ratio = 0.000174 m/yr  
1,15,1,1,98,98,1,  
0,day,-0.000174,m/yr,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#  
west,neumann,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
1,1,1,1,20,1,  
0,day,0.06,m/day,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#  
west,neumann,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
1,1,1,1,21,1,  
0,day,0.03,m/day,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#  
east,hydraulic gradient,outflow,outflow,outflow,outflow,  
#Hold head constant to keep h ~ 5 m at compliance point  
60,60,1,1,1,21,1,
```

```
0,day,786871.34,Pa,,,,,,,,,,  
#  
~Surface Flux Card  
50,  
Aqueous Volumetric Flux,m^3/yr,m^3,bottom,1,15,1,1,82,82,  
#Solute Flux,H-3,1/yr,,bottom,1,15,1,1,82,82,  
Solute Flux,I-129A,1/yr,,bottom,1,15,1,1,82,82,  
Solute Flux,I-129B,1/yr,,bottom,1,15,1,1,82,82,  
#Solute Flux,U-235,1/yr,,bottom,1,15,1,1,82,82,  
#Solute Flux,Np-237,1/yr,,bottom,1,15,1,1,82,82,  
Solute Flux,Sr-90,1/yr,,bottom,1,15,1,1,82,82,  
#Solute Flux,Zn-65,1/yr,,bottom,1,15,1,1,82,82,  
Solute Flux,Eu-155,1/yr,,bottom,1,15,1,1,82,82,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,bottom,1,15,1,1,22,22,  
#Solute Flux,H-3,1/yr,,bottom,1,15,1,1,22,22,  
Solute Flux,I-129A,1/yr,,bottom,1,15,1,1,22,22,  
Solute Flux,I-129B,1/yr,,bottom,1,15,1,1,22,22,  
#Solute Flux,U-235,1/yr,,bottom,1,15,1,1,22,22,  
#Solute Flux,Np-237,1/yr,,bottom,1,15,1,1,22,22,  
Solute Flux,Sr-90,1/yr,,bottom,1,15,1,1,22,22,  
#Solute Flux,Zn-65,1/yr,,bottom,1,15,1,1,22,22,  
Solute Flux,Eu-155,1/yr,,bottom,1,15,1,1,22,22,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,21,21,1,1,10,21,  
#Solute Flux,H-3,1/yr,,west,21,21,1,1,10,21,  
Solute Flux,I-129A,1/yr,,west,21,21,1,1,10,21,  
Solute Flux,I-129B,1/yr,,west,21,21,1,1,10,21,  
#Solute Flux,U-235,1/yr,,west,21,21,1,1,10,21,  
#Solute Flux,Np-237,1/yr,,west,21,21,1,1,10,21,  
Solute Flux,Sr-90,1/yr,,west,21,21,1,1,10,21,  
#Solute Flux,Zn-65,1/yr,,west,21,21,1,1,10,21,  
Solute Flux,Eu-155,1/yr,,west,21,21,1,1,10,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,21,21,1,1,17,21,  
#Solute Flux,H-3,1/yr,,west,21,21,1,1,17,21,  
Solute Flux,I-129A,1/yr,,west,21,21,1,1,17,21,  
Solute Flux,I-129B,1/yr,,west,21,21,1,1,17,21,  
#Solute Flux,U-235,1/yr,,west,21,21,1,1,17,21,  
#Solute Flux,Np-237,1/yr,,west,21,21,1,1,17,21,  
Solute Flux,Sr-90,1/yr,,west,21,21,1,1,17,21,  
#Solute Flux,Zn-65,1/yr,,west,21,21,1,1,17,21,  
Solute Flux,Eu-155,1/yr,,west,21,21,1,1,17,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,33,33,1,1,10,21,  
#Solute Flux,H-3,1/yr,,west,33,33,1,1,10,21,  
Solute Flux,I-129A,1/yr,,west,33,33,1,1,10,21,  
Solute Flux,I-129B,1/yr,,west,33,33,1,1,10,21,  
#Solute Flux,U-235,1/yr,,west,33,33,1,1,10,21,  
#Solute Flux,Np-237,1/yr,,west,33,33,1,1,10,21,  
Solute Flux,Sr-90,1/yr,,west,33,33,1,1,10,21,  
#Solute Flux,Zn-65,1/yr,,west,33,33,1,1,10,21,  
Solute Flux,Eu-155,1/yr,,west,33,33,1,1,10,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,33,33,1,1,17,21,  
#Solute Flux,H-3,1/yr,,west,33,33,1,1,17,21,  
Solute Flux,I-129A,1/yr,,west,33,33,1,1,17,21,
```

```
Solute Flux,I-129B,1/yr,,west,33,33,1,1,17,21,  
#Solute Flux,U-235,1/yr,,west,33,33,1,1,17,21,  
#Solute Flux,Np-237,1/yr,,west,33,33,1,1,17,21,  
Solute Flux,Sr-90,1/yr,,west,33,33,1,1,17,21,  
#Solute Flux,Zn-65,1/yr,,west,33,33,1,1,17,21,  
Solute Flux,Eu-155,1/yr,,west,33,33,1,1,17,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,41,41,1,1,10,21,  
#Solute Flux,H-3,1/yr,,west,41,41,1,1,10,21,  
Solute Flux,I-129A,1/yr,,west,41,41,1,1,10,21,  
Solute Flux,I-129B,1/yr,,west,41,41,1,1,10,21,  
#Solute Flux,U-235,1/yr,,west,41,41,1,1,10,21,  
#Solute Flux,Np-237,1/yr,,west,41,41,1,1,10,21,  
Solute Flux,Sr-90,1/yr,,west,41,41,1,1,10,21,  
#Solute Flux,Zn-65,1/yr,,west,41,41,1,1,10,21,  
Solute Flux,Eu-155,1/yr,,west,41,41,1,1,10,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,41,41,1,1,17,21,  
#Solute Flux,H-3,1/yr,,west,41,41,1,1,17,21,  
Solute Flux,I-129A,1/yr,,west,41,41,1,1,17,21,  
Solute Flux,I-129B,1/yr,,west,41,41,1,1,17,21,  
#Solute Flux,U-235,1/yr,,west,41,41,1,1,17,21,  
#Solute Flux,Np-237,1/yr,,west,41,41,1,1,17,21,  
Solute Flux,Sr-90,1/yr,,west,41,41,1,1,17,21,  
#Solute Flux,Zn-65,1/yr,,west,41,41,1,1,17,21,  
Solute Flux,Eu-155,1/yr,,west,41,41,1,1,17,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,58,58,1,1,10,21,  
#Solute Flux,H-3,1/yr,,west,58,58,1,1,10,21,  
Solute Flux,I-129A,1/yr,,west,58,58,1,1,10,21,  
Solute Flux,I-129B,1/yr,,west,58,58,1,1,10,21,  
#Solute Flux,U-235,1/yr,,west,58,58,1,1,10,21,  
#Solute Flux,Np-237,1/yr,,west,58,58,1,1,10,21,  
Solute Flux,Sr-90,1/yr,,west,58,58,1,1,10,21,  
#Solute Flux,Zn-65,1/yr,,west,58,58,1,1,10,21,  
Solute Flux,Eu-155,1/yr,,west,58,58,1,1,10,21,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,58,58,1,1,17,21,  
#Solute Flux,H-3,1/yr,,west,58,58,1,1,17,21,  
Solute Flux,I-129A,1/yr,,west,58,58,1,1,17,21,  
Solute Flux,I-129B,1/yr,,west,58,58,1,1,17,21,  
#Solute Flux,U-235,1/yr,,west,58,58,1,1,17,21,  
#Solute Flux,Np-237,1/yr,,west,58,58,1,1,17,21,  
Solute Flux,Sr-90,1/yr,,west,58,58,1,1,17,21,  
#Solute Flux,Zn-65,1/yr,,west,58,58,1,1,17,21,  
Solute Flux,Eu-155,1/yr,,west,58,58,1,1,17,21,  
#  
~Output Control Card  
48,  
21,1,10,  
21,1,11,  
21,1,12,  
21,1,13,  
21,1,14,  
21,1,15,  
21,1,16,  
21,1,17,
```

21,1,18,  
21,1,19,  
21,1,20,  
21,1,21,  
33,1,10,  
33,1,11,  
33,1,12,  
33,1,13,  
33,1,14,  
33,1,15,  
33,1,16,  
33,1,17,  
33,1,18,  
33,1,19,  
33,1,20,  
33,1,21,  
41,1,10,  
41,1,11,  
41,1,12,  
41,1,13,  
41,1,14,  
41,1,15,  
41,1,16,  
41,1,17,  
41,1,18,  
41,1,19,  
41,1,20,  
41,1,21,  
58,1,10,  
58,1,11,  
58,1,12,  
58,1,13,  
58,1,14,  
58,1,15,  
58,1,16,  
58,1,17,  
58,1,18,  
58,1,19,  
58,1,20,  
58,1,21,  
1,1,yr,m,8,8,8,  
8,  
aqueous saturation,,  
aqueous pressure,Pa,  
aqueous moisture content,,  
znc aqueous vol,m/yr,  
solute aqueous concentration,I-129A,,  
solute aqueous concentration,I-129B,,  
solute aqueous concentration,Sr-90,,  
solute aqueous concentration,Eu-155,,  
12,  
#1,yr,  
10,yr,  
100,yr,  
200,yr,  
500,yr,  
1000,yr,

1200, yr,  
1500, yr,  
2000, yr,  
#2500, yr,  
5000, yr,  
10000, yr,  
#20000, yr,  
50000, yr,  
100000, yr,  
#200000, yr,  
8,  
aqueous saturation,,  
aqueous pressure, Pa,  
aqueous moisture content,,  
znc aqueous vol, m/yr,  
solute aqueous concentration, I-129A,,  
solute aqueous concentration, I-129B,,  
solute aqueous concentration, Sr-90,,  
solute aqueous concentration, Eu-155,,  
rock/soil type,,

## E.10. Design Recharge, Surrogates 9 – 12 Input, Part B

~Simulation Title Card

1,  
INEEL Lengthwise Cross Section,  
WJ McMahon,  
CH2M Hill Hanford,  
November 29 2001,  
5:00 PM PDT,  
3,  
This input file is the contaminant transport run for the INEEL ICDF simulation  
This construction uses the geology developed by Pete Martian  
The input parameters are based on PM reports

~Solution Control Card

Restart,restart,  
Water w/ Solute Transport,  
2,  
0,day,20,yr,0.0007,yr,0.02,yr,1.25,8,1.e-6,  
20,yr,30,yr,0.02,yr,0.05,yr,1.25,8,1.e-6,  
8000,  
0,

~Grid Card

cartesian,  
60,1,98,  
# X Dimensions::160 m ICDF cell Total X Dimension 320 m  
0.,m,6@15,m,5@10,m,2@5,m,2@5,m,  
#20 m to screening model compliance point,  
2@5,m,1@4.,m,1@3.,m,1@2.,m,1@1.,m,  
#190 feet (or 58 m) to edge of landfill cap (less 20 m above)  
2@2.,m,1@3,m,1@4.,m,2@6.,m,1@4.,m,2@3.,m,2@2,m,1@1.,m,  
#190 feet (or 58 m) plus 20 m (less 58 m above)  
2@2.,m,1@3,m,1@4.,m,2@3.,m,1@2,m,1@1.,m,  
#190 feet (or 58 m) plus 100 m (less 78 m above)  
2@2.,m,1@3,m,2@4.,m,2@5.,m,5@8.,m,1@5.,m,1@4.,m,1@3.,m,1@2,m,1@1.,m,  
#One grid block to move last observation point off of boundary  
2@1.,m,  
# Y Dimensions (Y dimension not used)  
0.,m,1.,m,  
# Z Dimensions  
#Basalt Aquifer (Total = 76 m, Begin and End Lower 61 m) 9 Rows (Ignore 0)  
0.,m,2@12.,m,2@8.,m,2@6.,m,1@4.,m,1@3.,m,1@2.,m,  
#Basalt Aquifer Begin First 9 m of Upper 15 m 6 Rows  
6@1.5,m,  
#Basalt Aquifer Begin and End Upper 6 m  
# (7 m or 22 ft-note 6 m saturated and 1 m above water table) 6 Rows  
1@1,m,1@1,m,1@1,m,1@1,m,1@2,m,  
#Basalt (16.98 m or 57 ft-note that 1 m added to aquifer layer, 17.98 m = 59 ft)  
# 7 Rows  
1@2,m,1@2.32,m,1@2.75,m,1@3.25,m,1@3,m,1@2.15,m,1@1.51,m,  
#Sedimentary Interbed (7.01 m or 23 ft) 4 Rows  
1@1.51,m,1@2,m,1@2,m,1@1.5,m,  
#Basalt (39.93 m or 131 ft) 13 Rows

1@1.5,m,1@2,m,1@3,m,1@4,m,1@4,m,1@4.5,m,1@4.5,m,1@4,m,1@4,m,1@3,m,1@2.4,m,  
1@1.81,m,1@1.22,m,  
#Sedimentary Interbed (4.88 m or 16 ft) 4 Rows  
1@1.22,m,1@1.22,m,1@1.22,m,1@1.22,m,  
#Basalt (23.47 m or 77 ft) 9 Rows  
1@1.22,m,1@2,m,1@3,m,1@3.5,m,1@3.75,m,1@3.5,m,1@3,m,1@2,m,1@1.5,m,  
#Sedimentary Interbed (11.89 m or 39 ft) 6 Rows  
1@1.5,m,1@1.94,m,1@2.45,m,1@2.45,m,1@2.15,m,1@1.4,m,  
#Basalt (26.52 m or 87 ft) 13 Rows  
1@1.4,m,1@2,m,1@2,m,1@3,m,1@5,m,1@3,m,1@1.57,m,1@1.2,m,1@1,m,1@0.6,m,  
1@0.45,m,1@0.3,m,  
#Alluvium changed from 9 to 5 feet (1.52 m or 5 ft) 4 Rows  
1@0.30,m,1@0.46,m,1@0.46,m,1@0.30,m,  
#Clay Liner (0.91 m or 3 ft) 3 Rows  
1@0.30,m,1@0.31,m,1@0.30,m,  
#Operations Layer (0.91 m or 3 ft) 3 Rows  
1@0.30,m,1@0.31,m,1@0.30,m,  
#Waste (10.40 m or 34 ft adjusted to 12.56 m to account for cube vs  
trapezoid)  
# 11 Rows  
1@0.5,m,1@0.5,m,1@1,m,1@1,m,1@1.64,m,1@1.64,m,1@1.64,m,1@1,m,1@1,m,1  
@1,m,

~Rock/Soil Zonation Card

14,  
#Lower 61 m of Basalt Aquifer  
Basalt Aquifer,1,60,1,1,1,9,  
#Begin First 9 m of Upper 15 m of Basalt Aquifer  
Basalt Aquifer,1,60,1,1,10,15,  
#Upper 6 m of Basalt Aquifer  
Basalt Aquifer,1,60,1,1,16,21,  
#Lowest Vadose Basalt Layer  
Basalt,1,60,1,1,22,28,  
Interbed,1,60,1,1,29,32,  
Basalt,1,60,1,1,33,45,  
Interbed,1,60,1,1,46,49,  
Basalt,1,60,1,1,50,58,  
Interbed,1,60,1,1,59,64,  
Basalt,1,60,1,1,65,77,  
Alluvium,1,60,1,1,78,81,  
Clay,1,60,1,1,82,84,  
Operation Gravelly Sand,1,60,1,1,85,87,  
Waste Gravelly Sand,1,60,1,1,88,98,

~Inactive Nodes Card

#Integer,  
2,  
16,60,1,1,1,98,  
1,15,1,1,1,84,

~Mechanical Properties Card

#Particle density = 2650 kg/m<sup>3</sup> except for clay and old alluvium  
#Subgrade, attenuation barrier, and drain rock used in earlier models but  
#not used here  
#Basalt and interbed properties from P. Martian Screening Model  
Basalt Aquifer,,,0.06,0.06,,,Millington and Quirk,  
Interbed,,,0.487,0.487,,,Millington and Quirk,

Basalt,,,0.05,0.05,,,Millington and Quirk,  
#  
#Old Alluvium characteristics from Geotech report measurements  
# sat. moisture content (0.422, 0.426); dry bulk density (1.60, 1.64 g/cm^3)  
# particle density = 1.62 g/cm^3/(1-0.424) = 2.8125 g/cm^3  
Alluvium,2812.5,kg/m^3,0.424,0.424,,,Millington and Quirk,  
#Attenuation Barrier,,,0.400,0.400,,,Millington and Quirk,  
#Clay characteristics per discussion with J. Dehner  
Clay,2600,kg/m^3,0.390,0.390,,,Millington and Quirk,  
#Drain Rock,,,0.400,0.400,,,Millington and Quirk,  
Operation Gravelly Sand,,,0.275,0.275,,,Millington and Quirk,  
#Operation Gravelly Sand dry bulk density = 120 lb/ft^3 (per J. Dehner)  
#120 lb/ft^3\*0.4536 kg/lb\*1 ft^3/(0.3048 m/ft)^3 = 1922.25 kg/m^3  
#Porosity Operation Gravelly Sand = 1-(1922.25/2650)= 0.275  
Waste Gravelly Sand,,,0.266,0.266,,,Millington and Quirk,  
#Waste Gravelly Sand dry bulk density = 121.5 lb/ft^3 (per J. Dehner)  
#121.5 lb/ft^3\*0.4536 kg/lb\*1 ft^3/(0.3048 m)^3 = 1946.28 kg/m^3  
#Porosity Waste Gravelly Sand = 1-(1946.28/2650)= 0.266

~Hydraulic Properties Card  
#Properties from P. Martian Screening Model except old alluvium  
Basalt Aquifer,9.00e+01,darcy,,,3.00e-01,darcy,  
Interbed,6.7e-5,hc:cm/s,,,6.7e-5,hc:cm/s,  
Basalt,9.00e+01,darcy,,,3.00e-01,darcy,  
#Old Alluvium characteristics from Geotech report measurements  
# sat. hydraulic conductivity (1.2e-07 cm/s, 6.2e-08 cm/s, 7.1e-08 cm/s)  
Alluvium,1.2e-07,hc:cm/s,,,1.2e-07,hc:cm/s,  
#Subgrade,1e-04,hc:cm/s,,,1e-04,hc:cm/s,  
#Attenuation Barrier,1e-07,hc:cm/s,,,1e-07,hc:cm/s,  
Clay,1e-07,hc:cm/s,,,1e-07,hc:cm/s,  
#Drain Rock,3.0e-01,hc:cm/s,,,3.0e-01,hc:cm/s,  
Operation Gravelly Sand,1e-04,hc:cm/s,,,1e-04,hc:cm/s,  
Waste Gravelly Sand,1e-03,hc:cm/s,,,1e-03,hc:cm/s,

~Saturation Function Card  
#Parameters from P. Martian Screening Model except old alluvium  
#alpha, n, theta R, m  
#m only specified for basalts, otherwise default m = 1 - 1/n  
Basalt Aquifer,Nonhysteretic van Genuchten,4.0,1/m,4.5,0.0002,0.7777778,  
Interbed,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.142,,  
Basalt,Nonhysteretic van Genuchten,4.0,1/m,4.5,0.0002,0.7777778,  
#Old Alluvium characteristics from RETC fitting of Geotech report  
measurements  
Alluvium,Nonhysteretic van Genuchten,0.595,1/m,1.09,0.142,,  
#Subgrade,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.142,,  
#Attenuation Barrier,Nonhysteretic van Genuchten,0.800,1/m,1.090,0.07,,  
Clay,Nonhysteretic van Genuchten,0.800,1/m,1.109,0.07,,  
#Drain Rock,Nonhysteretic van Genuchten,493,1/m,2.190,0.005,,  
Operation Gravelly Sand,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.083,,  
Waste Gravelly Sand,Nonhysteretic van Genuchten,1.066,1/m,1.523,0.072,,  
#

~Aqueous Relative Permeability Card  
#m only specified for basalts, otherwise default m = 1 - 1/n  
Basalt Aquifer,Mualem,1.9,  
Interbed,Mualem,,  
Basalt,Mualem,1.9,  
Alluvium,Mualem,,

```
#Subgrade,Mualem,,  
#Attenuation Barrier,Mualem,,  
Clay,Mualem,,  
#Drain Rock,Mualem,,  
Operation Gravelly Sand,Mualem,,  
Waste Gravelly Sand,Mualem,,  
#  
~Solute/Fluid Interactions Card  
4,  
#H-3,conventional,1.0e-09,m^2/s,noncontinuous,,,  
I-129A,conventional,1.0e-09,m^2/s,noncontinuous,,,  
I-129B,conventional,1.0e-09,m^2/s,noncontinuous,,,  
#U-235,conventional,1.0e-09,m^2/s,noncontinuous,,,  
#Np-237,conventional,1.0e-09,m^2/s,noncontinuous,,,  
Sr-90,conventional,1.0e-09,m^2/s,noncontinuous,,,  
#Zn-65,conventional,1.0e-09,m^2/s,noncontinuous,,,  
Eu-155,conventional,1.0e-09,m^2/s,noncontinuous,,,  
0,  
#  
~Solute/Porous Media Interaction Card  
Basalt Aquifer,6.0,m,3.0,m,  
#H-3,0.0,cm^3/g,  
I-129A,0.0,cm^3/g,  
I-129B,0.0,cm^3/g,  
#U-235,0.24,cm^3/g,  
#Np-237,0.32,cm^3/g,  
Sr-90,0.48,cm^3/g,  
#Zn-65,0.64,cm^3/g,  
Eu-155,13.6,cm^3/g,  
#  
Interbed,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
I-129A,0.0,cm^3/g,  
I-129B,0.1,cm^3/g,  
#U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,  
Sr-90,12.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
Eu-155,340,cm^3/g,  
#  
Basalt,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
I-129A,0.0,cm^3/g,  
I-129B,0.0,cm^3/g,  
#U-235,0.0,cm^3/g,  
#Np-237,0.0,cm^3/g,  
Sr-90,0.0,cm^3/g,  
#Zn-65,0.0,cm^3/g,  
Eu-155,0,cm^3/g,  
#  
#Subgrade,5.0,m,0,m,  
#  
Alluvium,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
I-129A,0.0,cm^3/g,  
I-129B,0.1,cm^3/g,  
#U-235,6.0,cm^3/g,
```

```
#Np-237,8.0,cm^3/g,  
Sr-90,24.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
Eu-155,340,cm^3/g,  
#  
#Attenuation Barrier,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
#I-129A,1.0,cm^3/g,  
#I-129B,1.0,cm^3/g,  
#U-235,63.0,cm^3/g,  
#Np-237,55.0,cm^3/g,  
#Sr-90,200.0,cm^3/g,  
#Zn-65,2400.0,cm^3/g,  
#Eu-155,340,cm^3/g,  
#  
Clay,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
I-129A,1.0,cm^3/g,  
I-129B,1.0,cm^3/g,  
#U-235,63.0,cm^3/g,  
#Np-237,55.0,cm^3/g,  
Sr-90,200.0,cm^3/g,  
#Zn-65,2400.0,cm^3/g,  
Eu-155,340,cm^3/g,  
#  
#Drain Rock,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
#I-129A,0.0,cm^3/g,  
#I-129B,0.1,cm^3/g,  
#U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,  
#Sr-90,24.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
#Eu-155,340,cm^3/g,  
#  
Operation Gravelly Sand,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
I-129A,0.0,cm^3/g,  
I-129B,0.1,cm^3/g,  
#U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,  
Sr-90,12.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
Eu-155,340,cm^3/g,  
#  
Waste Gravelly Sand,5.0,m,0,m,  
#H-3,0.0,cm^3/g,  
I-129A,0.1,cm^3/g,  
I-129B,0.1,cm^3/g,  
#U-235,6.0,cm^3/g,  
#Np-237,8.0,cm^3/g,  
Sr-90,12.0,cm^3/g,  
#Zn-65,16.0,cm^3/g,  
Eu-155,340,cm^3/g,  
#  
~Initial Conditions Card  
Gas Pressure,Aqueous Pressure,
```

9,  
Aqueous Pressure,,,,,,,1,60,1,1,1,98,  
#Solute Volume Overwrite,H-3,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,I-129A,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,I-129B,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
#Solute Volume Overwrite,U-235,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
#Solute Volume Overwrite,Np-237,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,Sr-90,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
#Solute Volume Overwrite,Zn-65,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
Solute Volume Overwrite,Eu-155,0.0,1/m^3,0,,0,,1,60,1,1,1,98,  
#  
#Solute Volume Overwrite,H-3,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,I-129A,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,I-129B,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
#Solute Volume Overwrite,U-235,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
#Solute Volume Overwrite,Np-237,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,Sr-90,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
#Solute Volume Overwrite,Zn-65,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
Solute Volume Overwrite,Eu-155,1946.28,1/m^3,0,,0,,1,15,1,1,88,98,  
  
~Boundary Conditions Card  
3,  
#  
top,neumann,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,inflow aqueous,  
#0.0001 m/yr \* 1.74 ICDF Recharge Ratio = 0.000174 m/yr  
1,15,1,1,98,98,1,  
0,day,-0.000174,m/yr,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,  
#0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,0,1/m^3,  
#  
east,seepage face,outflow,outflow,outflow,outflow,  
#Emplace seepage face to account for leachate drain removal  
#Base of seepage face cell (Height = 0.3 m) set to atmospheric pressure  
#P = 101325 - 0.15 m \* 9793.52 = 99855.97  
15,15,1,1,85,85,1,  
0,day,99855.97,Pa,,,,,,,,,,,,,,,,,,  
#  
west,seepage face,outflow,outflow,outflow,outflow,  
#Emplace seepage face to account for leachate drain removal  
#Base of seepage face cell (Height = 0.3 m) set to atmospheric pressure  
#P = 101325 - 0.15 m \* 9793.52 = 99855.97  
1,1,1,1,85,85,1,  
0,day,99855.97,Pa,,,,,,,,,,  
#  
#  
~Surface Flux Card  
15,  
Aqueous Volumetric Flux,m^3/yr,m^3,top,1,15,1,1,85,85,  
#Solute Flux,H-3,1/yr,,top,1,15,1,1,85,85,  
Solute Flux,I-129A,1/yr,,top,1,15,1,1,85,85,  
Solute Flux,I-129B,1/yr,,top,1,15,1,1,85,85,  
#Solute Flux,U-235,1/yr,,top,1,15,1,1,85,85,  
#Solute Flux,Np-237,1/yr,,top,1,15,1,1,85,85,  
Solute Flux,Sr-90,1/yr,,top,1,15,1,1,85,85,  
#Solute Flux,Zn-65,1/yr,,top,1,15,1,1,85,85,

```
Solute Flux,Eu-155,1/yr,,top,1,15,1,1,85,85,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,west,1,1,1,1,85,85,  
Solute Flux,I-129A,1/yr,,west,1,1,1,1,85,85,  
Solute Flux,I-129B,1/yr,,west,1,1,1,1,85,85,  
Solute Flux,Sr-90,1/yr,,west,1,1,1,1,85,85,  
Solute Flux,Eu-155,1/yr,,west,1,1,1,1,85,85,  
#  
Aqueous Volumetric Flux,m^3/yr,m^3,east,15,15,1,1,85,85,  
Solute Flux,I-129A,1/yr,,east,15,15,1,1,85,85,  
Solute Flux,I-129B,1/yr,,east,15,15,1,1,85,85,  
Solute Flux,Sr-90,1/yr,,east,15,15,1,1,85,85,  
Solute Flux,Eu-155,1/yr,,east,15,15,1,1,85,85,  
#  
~Output Control Card  
12,  
1,1,85,  
5,1,85,  
10,1,85,  
15,1,85,  
1,1,88,  
5,1,88,  
10,1,88,  
15,1,88,  
1,1,98,  
5,1,98,  
10,1,98,  
15,1,98,  
1,1,yr,m,8,8,8,  
8,  
aqueous saturation,,  
aqueous pressure,Pa,  
aqueous moisture content,,  
znc aqueous vol,m/yr,  
solute aqueous concentration,I-129A,,  
solute aqueous concentration,I-129B,,  
solute aqueous concentration,Sr-90,,  
solute aqueous concentration,Eu-155,,  
30,  
1,yr,  
2,yr,  
3,yr,  
4,yr,  
5,yr,  
6,yr,  
7,yr,  
8,yr,  
9,yr,  
10,yr,  
11,yr,  
12,yr,  
13,yr,  
14,yr,  
15,yr,  
16,yr,  
17,yr,  
18,yr,
```

19, yr,  
20, yr,  
21, yr,  
22, yr,  
23, yr,  
24, yr,  
25, yr,  
26, yr,  
27, yr,  
28, yr,  
29, yr,  
30, yr,  
8,  
aqueous saturation,,  
aqueous pressure, Pa,  
aqueous moisture content,,  
znc aqueous vol, m/yr,  
solute aqueous concentration, I-129A,,  
solute aqueous concentration, I-129B,,  
solute aqueous concentration, Sr-90,,  
solute aqueous concentration, Eu-155,,  
rock/soil type,,

431.02  
01/30/2003  
Rev. 11

**ENGINEERING DESIGN FILE**

EDF-ER-275  
Revision 3  
Page 212 of 228

This page intentionally left blank.

## **Appendix F**

### **Analysis of Fate and Transport for the ICDF Landfill Waste Acceptance Criteria**

431.02  
01/30/2003  
Rev. 11

**ENGINEERING DESIGN FILE**

EDF-ER-275  
Revision 3  
Page 214 of 228

This page intentionally left blank.

TECHNICAL MEMORANDUM

CH2MHILL

# Analysis of Ni-59, Ni-63, and Fe-55 Fate and Transport for the ICDF Landfill Waste Acceptance Criteria

**PREPARED FOR:** ICDF Implementation Project

**PREPARED BY:** CH2M HILL

**COPIES:**  
Lorin Young  
Chuck Miller

Craig Sump  
Bert Day

**DATE:** September 15, 2003

The purpose of this technical memorandum is to evaluate the cumulative long-term groundwater impact of Ni-59, Ni-63, and Fe-55 identified in waste to be disposed at the INEEL CERCLA Disposal Facility (ICDF).

## Requirements

For given soil concentrations, the impact of the identified radionuclides will be evaluated against Remedial Action Objectives (RAOs) for protection of groundwater. Following these evaluations, a recommendation will be provided regarding the correct path forward for the inclusion of the identified radionuclides into the ICDF waste acceptance criteria based on meeting groundwater RAOs.

## Background

The INEEL plans to dispose remediation wastes at the INEEL CERCLA Disposal Facility (ICDF). Recent evaluations identified three radionuclides above detection which had not been included in the original design inventory. As such, these radionuclides were not assigned WAC guideline concentrations or mass limits. These radionuclides are Nickel-59 (Ni-59), Nickel-63 (Ni-63), and Iron-55 (Fe-55).

## Methodology

The identified radionuclides are evaluated against applicable long term groundwater protection Remedial Action Objectives (RAOs) as specified in the Final Record of Decision, Idaho Nuclear Technology and Engineering Center, Operable Unit 3-13 (DOE-ID-1999) (ROD). For these radionuclides, the applicable RAO's are cumulative excess lifetime carcinogenic risk (ELCR) less than 1E-04 and comparison to National Primary Drinking Water Standards maximum contaminant levels (MCLs) in groundwater. This evaluation involves calculating estimated groundwater concentrations for each radionuclide, calculating carcinogenic risk contribution, and comparing groundwater concentrations to applicable MCLs.

### **Calculation of Groundwater Concentrations**

Fate and transport of each constituent was evaluated by assigning surrogate contaminant distribution coefficients ( $K_d$ s) consistent EDF-ER-275. The radionuclides are assigned the same surrogate  $K_d$  values as were originally assigned to the non-isotopic, total metal elemental forms. All three radionuclides are assigned to the surrogate  $K_d$  #7 (weighted average  $K_d$  of 18.59 cm<sup>3</sup>/g for the constructed model through all layers of the soil profile). Groundwater concentrations are calculated for each radionuclide over the simulation period of 1 million years and are adjusted for radiological decay.

### **Determining Carcinogenic Risk**

These constituents were not included in the original WAC, and therefore ELCR risk factors have not been calculated. For this preliminary analysis, the carcinogenic risk factor developed for Samarium-151 (Sm-151) is used as a surrogate risk factor for the three radionuclides. The selection of Sm-151 as an appropriate surrogate is based on risk factors developed for a similar residential exposure risk assessment model which included Ni-59, Ni-63, Fe-55, and several other radionuclides. This risk assessment model was developed to evaluate long-term groundwater impacts in support of closure activities underway for DOE Hanford single-shell radioactive storage tanks (Rittman, 2003). The risk factors developed for Ni-59, Ni-63, Fe-55 and Sm-151, in units of risk per pCi/L, are all very similar in the Hanford risk assessment model. Assuming that the risk assessment models are analogous in approach in terms of exposure scenarios, the risk factor for Sm-151 calculated for the ICDF exposure scenario is an appropriate surrogate risk factor value for Ni-59, Ni-63, and Fe-55. This factor coupled with calculated groundwater concentrations is used to derive carcinogenic risk contributions.

### **Comparison to National Primary Drinking Water Standards (MCLs)**

Ni-59, Ni-63, and Fe-55 are all beta-photon emitters and as their groundwater MCLs, therefore, are based on a maximum of 4 mrem/yr cumulative beta-photon dose to the whole body or any target organ. Target organs for each radionuclide are presented in Table 1. Individual target organ doses for these radionuclides were compared to cumulative ICDF results presented in DOE-ID, 2003.

## **Results and Discussion**

### **Groundwater Concentrations**

Input parameters and peak groundwater concentrations for Ni-59, Ni-63, and Fe-55, at the new soil concentrations, are presented in Table 1.

TABLE 1

Input Parameters and Peak Groundwater Concentrations for Ni-59, Ni-63, and Fe-55 at Measured Soil Concentrations.

Constituent	New Soil Concentration (pCi/kg) <sup>1</sup>	Kd surrogate bin <sup>2</sup>	Half-Life (yrs) <sup>3</sup>	MCL Target Organ <sup>4</sup>	ELCR Risk Factor <sup>5</sup>	Peak Groundwater Concentration (pCi/L)	Peak Time (yrs)
Ni-59	9.50E+06	7	7.60E+04	Bone	9.51E+07	3.38E-04	512,566
Ni-63	6.00E+07	7	1.00E+02	Bone	9.51E+07	1.15E-178	56,000
Fe-55	2.00E+09	7	2.70E+00	Spleen	9.51E+07	0.00E+00	NA

<sup>1</sup>Soil Concentration provided via e-mail originating from Jim Curnutt on 8/27/03.

<sup>2</sup>As reported in EDF-ER-275.

<sup>3</sup> "Table of Nuclides (c) 2000-2002 Nuclear Data Evaluation Lab. Korea Atomic Energy Research Institute <http://www2.bnl.gov/ton/index.html>".

<sup>4</sup>NBS 1963, Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air or Water for Occupational Exposure, National Bureau of Standards Handbook 69, as amended, U.S. Department of Commerce, Washington D.C.

<sup>5</sup>ELCR risk factor developed for Sm-151 in EDF-ER-275 used as surrogate risk factor.

Ni-63 and Fe-55 do not reach groundwater in detectable quantities over the 1 million year simulation period because of relatively short half-lives and low mobility in the soil (i.e. high Kd value). No further consideration of these radionuclides is warranted from a long-term groundwater quality perspective.

Nickel-59, because of its longer half-life, exhibits the potential to impact groundwater at detectable concentrations depending on initial soil concentrations. At the reported soil concentration of 9.50 E+06 pCi/kg, Ni-59 exhibits a peak groundwater concentration of 33.8E-04 pCi/L. A concentration versus time curve for Ni-59 is presented in Figure 1., Attachment A.

### Carcinogenic Risk Contribution

A plot of cumulative carcinogenic risk over time curve for all constituents currently in the design inventory exhibits two periods of peak risk. The first and maximum peak occurs approximately 50,000 years in the future and represents the cumulative risk contribution from highly mobile carcinogenic constituents (i.e. Iodine-129, Technetium-99,). The second peak occurs near the end of the 1 million year simulation period and represents the risk contribution from constituents with a high Kd value and long half-lives. Ni-59 falls into this second grouping and primarily contributes to this second risk peak. The cumulative risk versus time curve is presented in Figure 2, Attachment A. Individual risk versus time curve for Ni-59 is presented in Figure 3, Attachment A.

Nickel-59 exhibits an estimated peak groundwater concentration, and therefore peak risk contribution, at approximately 500,000 yrs. At this time, the cumulative risk is approximately 1.32E-05 and is rising towards the second cumulative peak risk value of 1.69E-05. At the time of the second cumulative peak risk, the risk contribution from Ni-59 is declining from its individual peak. Individual and Cumulative risk values are summarized in Table 3 for these discussion points. At its peak value, Ni-59 contributes a risk of 3.55E-12. This risk value is nearly eight orders of magnitude below the maximum target risk of 1E-04. Nickel-59 is not a major carcinogenic risk contributor.

**TABLE 2**  
Summary of Carcinogenic Risk Contributed By Ni-59 at Measured Soil Concentrations.

Constituent	Individual Risk Contribution			Cumulative Risk Contribution	
	New Soil Concentration (pCi/kg) <sup>1</sup>	Peak Groundwater Concentration (pCi/L)	Risk Contribution at Time of Peak GW Concentration	Maximum Cumulative Risk After Arrival of Ni-59.	Additional Risk Contributed by Ni-59 at Time of Maximum Cumulative Risk
Ni-59	9.50E+06	3.38E-04	3.55E-12	1.67E-05	1.76E-12

<sup>1</sup>Soil Concentration provided via e-mail originating from Jim Curnutt on 8/27/03

### MCL Comparison

At the calculated peak groundwater concentration, Ni-59 is evaluated against the beta-photon target organ MCL. The target organ for Ni-59 is bone. Strontium-89 is the only other radionuclide included in the design inventory that contributes to the target organ dose for bone. Because of its short half-life (0.138 yrs), Sr-89 does not reach groundwater at detectable concentrations. The total beta-photon dose contribution from Ni-59 is calculated as described in appendix B of EDF-ER-275. At the time of peak groundwater concentration for Ni-59, there are no constituents contributing whole body dose (Cs-135, Cs-136, Cs-137, or tritium) and target organ dose to bone is wholly attributed to Ni-59. The calculated beta-photon dose is presented in Table 3. The calculated dose is approximately six orders of magnitude below the MCL limit of 4 mrem/yr.

**TABLE 3.**  
Comparison to Target Organ MCL for Ni-59 at Reported Soil Concentration

Concentration of Ni-59 in Soil (pCi/kg)	Peak Groundwater Concentration (pCi/L)	Target Organ (Bone) MCL C4 Concentration (pCi/L) <sup>1</sup>	Contribution to 4 mrem/yr MCL Maximum Dose (Target Organ: Bone) mrem/yr.

**TABLE 3..**  
Comparison to Target Organ MCL for Ni-59 at Reported Soil Concentration

Concentration of Ni-59 in Soil (pCi/kg)	Peak Groundwater Concentration (pCi/L)	Target Organ (Bone) MCL C4 Concentration (pCi/L) <sup>1</sup>	Contribution to 4 mrem/yr MCL Maximum Dose (Target Organ: Bone) mrem/yr.
9.50E+06	3.38E-04	300	4.51E-06

<sup>1</sup>C4 concentration is the concentration equivalent to a total dose of 4 mrem/yr. Division by 4 results in pCi per mrem/yr. EPA, National Interim Primary Drinking Water Regulations, EPA-570/9-76-003, U.S. Environmental Protection Agency, Office of Water Supply, Washington D.C.

### Inclusion in Existing WAC

To account for potentially higher Ni-59 soil concentrations, an upper bounding concentration is evaluated which is much higher than the reported soil concentration. The selected concentration is derived from the current WAC for total nickel (metal). The current WAC for nickel (350 mg/kg) is converted into a concentration of Ni-59 (in pCi/kg) using a specific activity of 7.99E+07 pCi/mg. The objective of this evaluation is to demonstrate that Ni-59 is not a major risk driver and can be adequately managed utilizing the current WAC guidelines for nickel metal. Resulting carcinogenic risk contribution and MCL dose at peak groundwater concentration resulting from this soil concentration are presented in Table 4. The results are orders of magnitude below the target objectives for carcinogenic risk and beta-photon target organ dose.

**TABLE 4**  
Additional Carcinogenic Risk Contributed by Ni-59 at Current WAC Concentration for Nickel Metal (assuming all Ni-59).

Constituent	Current WAC Concentration for Nickel (metal) (mg/kg) <sup>1</sup>	Current WAC Concentration for Nickel (metal) converted to pCi/kg Ni-59.	Peak GW Concentration (pCi/L)	Risk Contribution at Time of Peak GW Concentration	Beta-Photon Dose (MCL = 4 mrem/yr cumulative dose) mrem/yr
Ni-59	3.50E+02	2.80E+10	9.94E-01	1.05E-08	1.32E-02

<sup>1</sup> From DOE-ID 10865.

2Calculated as described in EDR-EF-275.

## **Recommended Path Forward**

Current WAC for nickel and iron (totals) is sufficient to limit the potential risk to groundwater presented by Ni-59, Ni-63, and Fe-55. Constituent specific risk factors and modeling should be considered should a more quantitative contribution to cumulative risk be warranted. Final WAC for Ni-59 may be limited by considerations other than groundwater protection RAOs (i.e. liner integrity, worker exposure, etc.)

EDF-ER-275 should be amended to include the results of this memo.

## **References**

EDF-ER-275, 2002, "Fate and Transport Modeling Results and Summary Report", Rev 2., Environmental Restoration Program, Idaho National Engineering and Environmental Laboratory, 2002.

DOE-ID, 2003, *Waste Acceptance Criteria for ICDF Landfill*, DOE/ID-10865, Rev.3, U.S. Department of Energy Idaho Operations Office, Idaho Falls, Idaho, July 2003.

Rittman, P.D., 2003, Exposure Scenarios and Unit Dose Factors for Hanford Tank Waste Performance Assessments, HNF-SD-WM-TI-707, Revision 2, 2003, Fluor Daniel Hanford, Inc., Richland, WA.

Curnutt, Jim, via e-mail, Subject: RE: Evaluations of New Waste Constituents, 8/27/03.

## **Attachment A**

Figure 1. Concentration Versus Time Curve for Ni-59.

Figure 2. Cumulative Carcinogenic Risk Versus Time Curve at WAC Maximum Concentrations (From DOE-ID 10865, 2003).

Figure 3. Carcinogenic Risk Versus Time for Ni-59.

Groundwater Concentration vs Time Curve for Ni-59

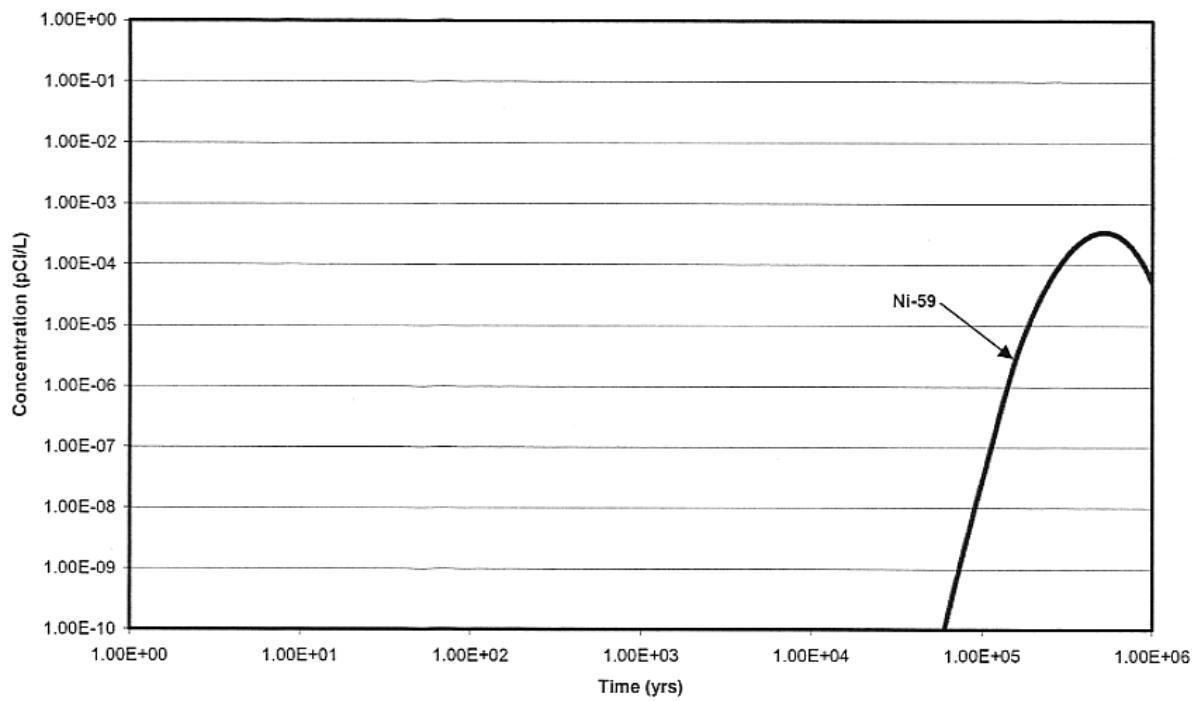


Figure 1. Concentration Versus Time Curve for Ni-59.

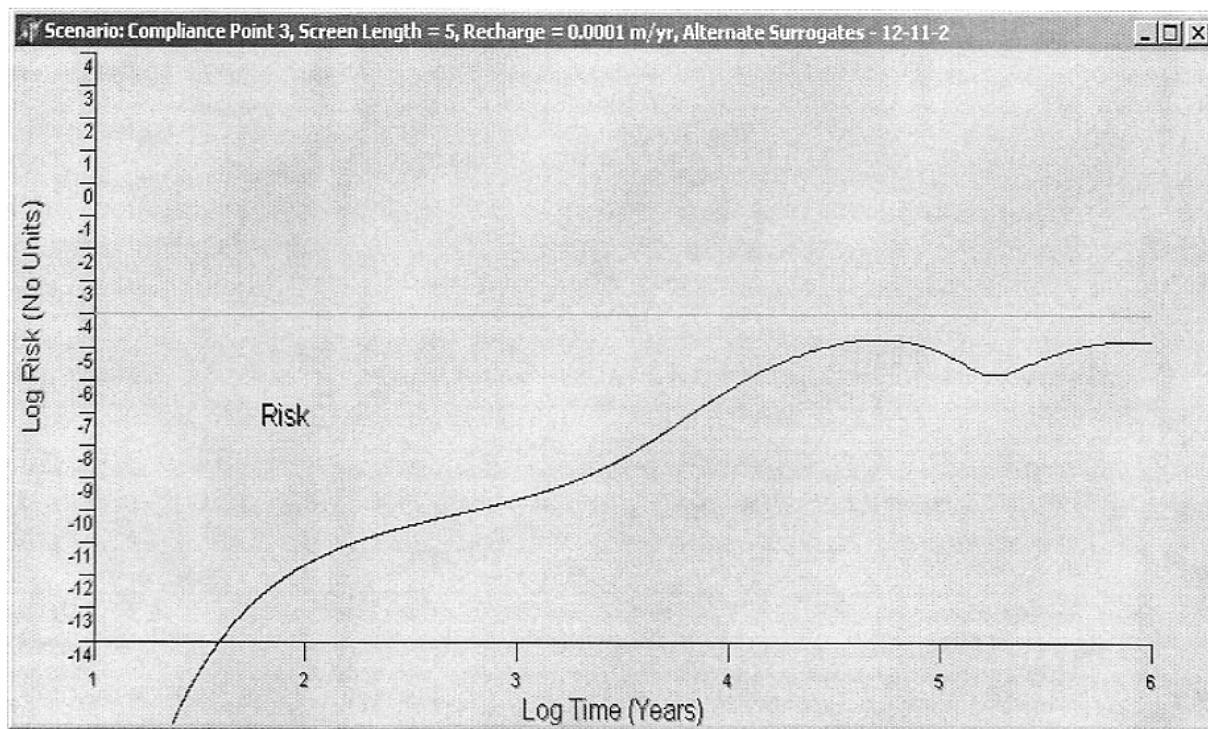


Figure 2. Cumulative Carcinogenic Risk Versus Time Curve at WAC Maximum Concentrations (From DOE-ID 10865, 2003).

Carcinogenic Risk vs Time Curve for Ni-59

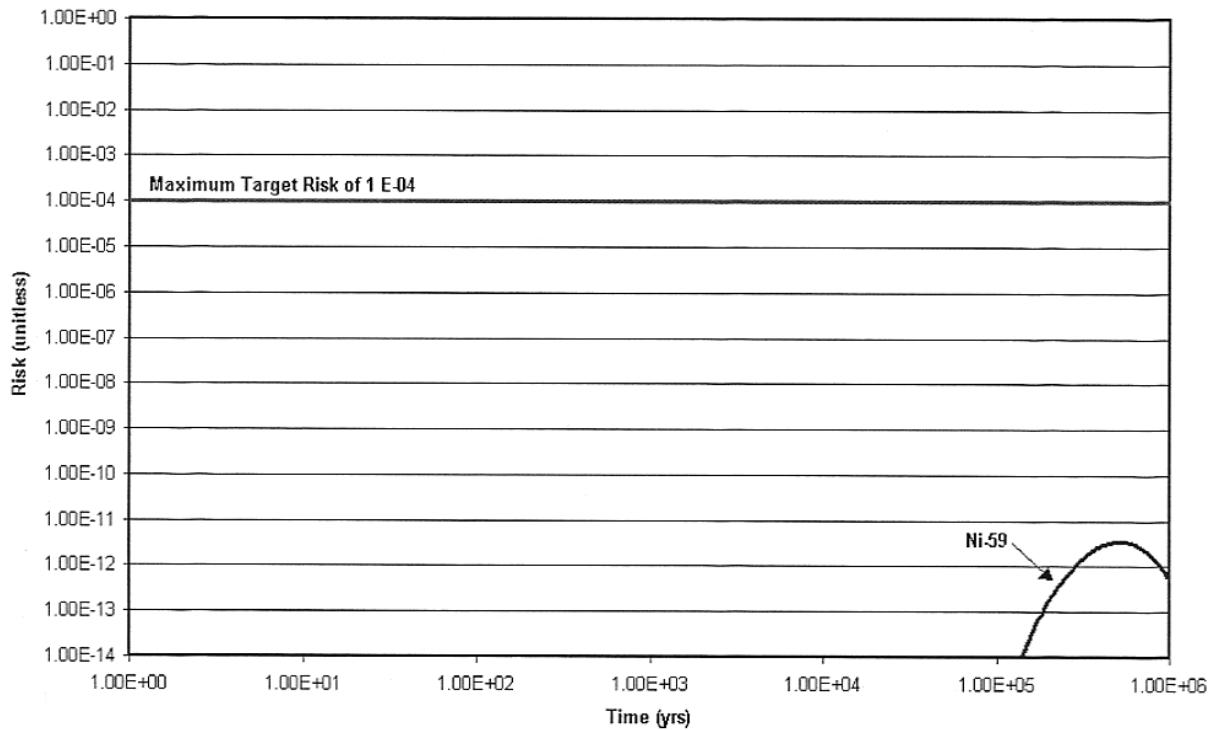


Figure 3. Carcinogenic Risk Versus Time for Ni-59.

## Analysis of Fate and Transport for the ICDF Landfill Waste Acceptance Criteria

PREPARED FOR: ICDF Implementation Project  
PREPARED BY: CH2M HILL  
DATE: March 24, 2004

The purpose of this technical memorandum is to evaluate the leachate and long-term groundwater concentrations of several constituents, identified in waste to be disposed at the INEEL CERCLA Disposal Facility (ICDF).

### Requirements

For the given soil concentrations, estimate groundwater concentrations of the given constituents at the assessment point and calculate the groundwater risk associated with each constituent.

### Background

The INEEL plans to dispose of remediation wastes at the ICDF. Recent evaluations identified constituents which had not been included in the original design inventory or were included in the original design inventory but are included in this analysis because it has been found that the soil concentration of each constituent is significantly greater than that of the original design inventory. As such, these constituents were not assigned WAC guideline concentrations or mass limits, or these limits have been revised due to the increased soil concentration. The list of constituents can be found in Table 1.

In addition to the constituents identified in Table 1, four other constituents were identified that are not included in this analysis based on the following reasons. Bromide, phosphate, and silicon are naturally occurring compounds that are not found in the environment as stand alone constituents. These compounds do not have available toxicity criteria and therefore risk to human health or the environment cannot be evaluated. Polyvinyl chloride is an inert plastic that does not tend to partition into the water phase in the environment. Additionally, it does not have available toxicity criteria, therefore risk to human health or the environment cannot be evaluated.

### Methodology

This evaluation involves calculating estimated groundwater concentrations and associated risk for the given constituents according to the methodologies presented in EDF-ER-275.

### Calculation of Groundwater Concentrations

Fate and transport of each constituent was evaluated by assigning the constituents surrogate contaminant distribution coefficients (Kds) consistent with EDF-ER-275 and updating the spreadsheet model to predict the groundwater concentration of each contaminant as a function of time.

## Results and Discussion

### Groundwater Concentrations

Input parameters and peak groundwater concentrations for the constituents at the new soil concentrations are presented in Table 1.

**TABLE 1**  
Input Parameters and Peak Groundwater Concentrations at a Measured Soil Concentration.

Constituent	Soil Concentration (pCi/kg or mg/kg) <sup>a</sup>	Kd Surrogate Bin <sup>b</sup>	Half-Life (Years)	Peak Concentration (pCi/L or mg/L)	Peak Concentration Arrival Time (Years)
<b>Inorganics</b>					
Tin	3.02E+00	Surrogate 1	NA	3.63E-04	3.13E+04
<b>Organics</b>					
1,2,3,4,6,7,8,9-OCDD	6.86E-02	Surrogate 7	NA	3.34E-09	1.00E+06
1,2,3,4,6,7,8,9-OCDF	1.43E-02	Surrogate 7	NA	6.97E-10	1.00E+06
1,2,3,4,6,7,8-HxCDD	4.60E-02	Surrogate 7	NA	2.24E-09	1.00E+06
1,2,3,4,6,7,8-HxCDF	1.20E-01	Surrogate 7	NA	5.85E-09	1.00E+06
1,2,3,4,7,8,9-HxCDF	5.85E-04	Surrogate 7	NA	2.85E-11	1.00E+06
1,2,3,4,7,8-HxCDD	1.09E-04	Surrogate 7	NA	5.31E-12	1.00E+06
1,2,3,4,7,8-HxCDF	1.96E-01	Surrogate 7	NA	9.56E-09	1.00E+06
1,2,3,6,7,8-HxCDD	8.37E-04	Surrogate 7	NA	4.08E-11	1.00E+06
1,2,3,6,7,8-HxCDF	1.01E-02	Surrogate 7	NA	4.92E-10	1.00E+06
1,2,3,7,8,9-HxCDD	2.35E-03	Surrogate 7	NA	1.15E-10	1.00E+06
1,2,3,7,8,9-HxCDF	2.21E-05	Surrogate 7	NA	1.08E-12	1.00E+06
1,2,3,7,8-PeCDD	1.06E-04	Surrogate 7	NA	5.17E-12	1.00E+06
1,2,3,7,8-PeCDF	9.34E-04	Surrogate 7	NA	4.55E-11	1.00E+06
2,3,4,6,7,8-HxCDF	1.62E-02	Surrogate 7	NA	7.90E-10	1.00E+06
2,3,4,7,8-PeCDF	6.26E-03	Surrogate 7	NA	3.05E-10	1.00E+06
2,3,7,8-TCDD	4.11E-06	Surrogate 7	NA	2.00E-13	1.00E+06
2,3,7,8-TCDF	5.52E-02	Surrogate 7	NA	2.69E-09	1.00E+06

**TABLE 1**  
Input Parameters and Peak Groundwater Concentrations at a Measured Soil Concentration.

Constituent	Soil Concentration (pCi/kg or mg/kg) <sup>a</sup>	Kd Surrogate Bin <sup>b</sup>	Half-Life (Years)	Peak Concentration (pCi/L or mg/L)	Peak Concentration Arrival Time (Years)
1,2-Dichloroethane	2.52E+01	Surrogate 2	6.37E-01	6.80E-28	2.79E+01
2-Nitroanaline	3.40E+00	Surrogate 1	NA	4.08E-04	3.13E+04
3-Nitroanaline	3.40E+00	Surrogate 1	NA	4.08E-04	3.13E+04
4-Nitroanaline	3.40E+00	Surrogate 1	NA	4.08E-04	3.13E+04
Aroclor-1262 <sup>c</sup>	4.95E+00	Surrogate 8	7.00E+00	0.00E+00	1.00E+06
Bromomethane	4.00E+00	Surrogate 1	1.04E-01	3.28E-81	2.26E+01
Styrene	4.25E+04	Surrogate 3	3.10E-01	1.13E-68	5.85E+01
Vinyl Chloride	1.22E+01	Surrogate 2	NA	1.20E-03	3.53E+04
<b>Radionuclides</b>					
U-233	1.64E+05	Surrogate 4	1.59E+05	4.23E-02	4.43E+05

<sup>a</sup>As provided by BBWI in CN-23 dated February 3, 2004.

<sup>b</sup>Determined in accordance with EDF-ER-275, "Fate and Transport Modeling Results and Summary Report".

<sup>c</sup>Aroclor-1260 is used as a surrogate for Aroclor-1262. Values taken from EDF-ER-275, "Fate and Transport Modeling Results and Summary Report".

### MCL Comparison

Federal drinking water maximum contaminant levels (MCLs) are available for 2,3,7,8 tetrachlorodibenzodioxin (TCDD) ( $3 \times 10^{-8}$  mg/L), polychlorinated biphenyls (PCBs) (0.0005 mg/L), 1,2-dichloroethane (0.005 mg/L), styrene (0.1 mg/L), and vinyl chloride (0.002 mg/L). Uranium-233 has a gross alpha particle MCL of 15 pCi/L. Peak groundwater concentrations for these constituents do not exceed their respective MCLs (see Table 2).

### Long-Term Risk

Risk-based concentrations (RBCs) were developed for each of the contaminants presented in Table 1 using the procedure described in EDF-ER-275. RBCs for each constituent evaluated are presented in Table 2. The peak groundwater concentrations for all constituents evaluated were below their respective RBC. Because all concentrations are less than their respecitve RBC value, carcinogenic constituents are less than the excess lifetime cancer risk of  $1 \times 10^{-4}$  and the hazard quotients for noncarcinogenic constituents are less than 1.

**TABLE 2**  
Risk Based Concentrations.

Constituent	Peak Groundwater Concentration (pCi/L or mg/L)	Maximum Contaminant Level (pCi/L or mg/L)	Does Groundwater Concentration Exceed MCL?	Groundwater Risk-Based Concentration (pCi/L or mg/L)	Does Groundwater Concentration Exceed RBC?
<b>Inorganics</b>					
Tin	3.63E-04	--	--	1.73E+01	No
<b>Organics</b>					
1,2,3,4,6,7,8,9-OCDD	3.34E-09	--	--	1.80E-01	No
1,2,3,4,6,7,8,9-OCDF	6.97E-10	--	--	1.80E-01	No
1,2,3,4,6,7,8-HxCDD	2.24E-09	--	--	1.80E-03	No
1,2,3,4,6,7,8-HxCDF	5.85E-09	--	--	1.80E-03	No
1,2,3,4,7,8,9-HxCDF	2.85E-11	--	--	1.80E-03	No
1,2,3,4,7,8-HxCDD	5.31E-12	--	--	1.80E-04	No
1,2,3,4,7,8-HxCDF	9.56E-09	--	--	1.80E-04	No
1,2,3,6,7,8-HxCDD	4.08E-11	--	--	1.80E-04	No
1,2,3,6,7,8-HxCDF	4.92E-10	--	--	1.80E-04	No
1,2,3,7,8,9-HxCDD	1.15E-10	--	--	1.80E-04	No
1,2,3,7,8,9-HxCDF	1.08E-12	--	--	1.80E-04	No
1,2,3,7,8-PeCDD	5.17E-12	--	--	1.80E-05	No
1,2,3,7,8-PeCDF	4.55E-11	--	--	3.61E-04	No
2,3,4,6,7,8-HxCDF	7.90E-10	--	--	1.80E-04	No
2,3,4,7,8-PeCDF	3.05E-10	--	--	3.61E-05	No
2,3,7,8-TCDD	2.00E-13	3.0E-08	No	1.80E-05	No
2,3,7,8-TCDF	2.69E-09	--	--	1.80E-04	No
1,2-Dichloroethane	6.80E-28	0.005	No	7.99E-03	No
2-Nitroaniline	4.08E-04	--	--	8.16E-04	No
3-Nitroaniline	4.08E-04	--	--	8.20E-04	No
4-Nitroaniline	4.08E-04	--	--	8.20E-04	No
Aroclor-1262 <sup>c</sup>	0.00E+00	0.0005	No	3.04E-01	No
Bromomethane	3.28E-81	--	--	6.72E-03	No
Styrene	1.13E-68	0.1	No	1.28E+00	No
Vinyl Chloride	1.20E-03	0.002	No	5.52E+00	No
<b>Radionuclides</b>					

**TABLE 2**  
Risk Based Concentrations.

Constituent	Peak Groundwater Concentration (pCi/L or mg/L)	Maximum Contaminant Level (pCi/L or mg/L)	Does Groundwater Concentration Exceed MCL?	Groundwater Risk-Based Concentration (pCi/L or mg/L)	Does Groundwater Concentration Exceed RBC?
U-233	4.23E-02	15	No	7.35E+04	No

## **Conclusions**

Tin, 2-nitroaniline, 3-nitroaniline, 4-nitroaniline, 1,2-dichloroethane, bromomethane, and styrene are noncarcinogenic constituents, the remaining constituents evaluated are considered carcinogenic constituents. The excess lifetime cancer risk is less than  $1 \times 10^{-4}$  for all carcinogenic constituents and the hazard quotients for noncarcinogenic constituents are less than 1. For constituents with available MCLs, peak groundwater concentrations are less than their respective MCLs. Based upon previous conclusions, the addition of these constituents to the waste inventory at ICDF should not negatively impact the groundwater beneath the site. EDF-ER-275 should be revised to include the results of this memorandum.

## **References**

EDF-ER-275, 2002, "Fate and Transport Modeling Results and Summary Report", Rev 2., Environmental Restoration Program, Idaho National Engineering and Environmental Laboratory, 2002.